CHAPTER 4

TROUBLESHOOTING ELECTRICAL SYSTEMS

In the early days of the automobile, only its ignition system depended on electricity for operation. However, in today's automobile and construction equipment, electricity operates the ignition, lighting, and starting systems and many accessories, such as control units on automatic transmissions and overdrives, choke controls, emission controls, and air conditioning.

Storage batteries, generators, regulators, and other units are required to provide an adequate source of electrical current for construction and automotive equipment. The Construction Mechanic is responsible for maintaining the parts and units of the electrically operated systems and accessories on this equipment. Electrical repairs and adjustments, however, are special tasks that require the know-how of an expert-a person trained for this kind of work; in other words, an automotive electrician.

As a CM1, when you supervise mechanics who perform these special tasks in the shop or garage, you will need automotive electrical testing equipment. For example, in troubleshooting batteries and generators you save time and reduce damage to equipment by using ammeters and voltmeters instead of hit-and-miss methods.

All units in an automotive electrical system operate on the basic principles described in this chapter. You can find more on automotive electricity in *Construction Mechanic 3 & 2* and U.S. Army TM-9-8000, *Principles of Automotive Vehicles.* This chapter includes the techniques of troubleshooting the charging, cranking, ignition, and lighting systems, and other electrical accessories.

AC CHARGING SYSTEMS

The output requirements of automotive electrical generators have increased considerable y in recent years because of the growing popularity of current-consuming electrical accessories, such as two-way radios and radiotelephones for communications, heavy-duty heaters, and air-conditioners.

A conventional dc generator built to produce the required amount of electricity at both high- and low-speed ranges requires an increase in size which limits application. An ac generator (ALTERNATOR) has been developed that can be used with a rectifier bridge to produce enough current to fulfill almost any need over a speed range that varies from idle-to-top engine speed.

ALTERNATORS

The small size of the alternator makes it adaptable to almost any application. It is mechanically constructed to withstand extreme heat, vibrations, and top speeds met in normal service.

A review of *Construction Mechanic 3 & 2* will show that the alternator and the conventional dc generator operate on the same basic principles. The rotor assembly in the alternator does the same job as the field coil and pole shoe assembly in the dc generator. The stator assembly in an alternator has the same function as the armature in a dc generator while in a fixed position. The stator maybe either Y or delta connected to fit the application. (See fig. 4-1.) Normally, the delta-connected alternator is found where lower voltage, but

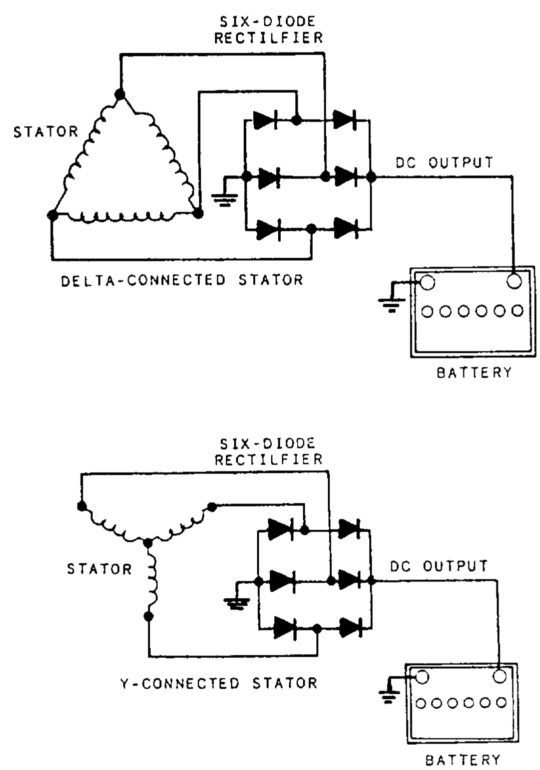


Figure 4-1.-Types of alternator internal windings.

higher current is required. The Y-connected alternator provides higher voltage and moderate current. The device for converting alternating current to direct current is the rectifier bridge. The rectifier bridge may be mounted internally within the alternator casing, or it may be mounted externally.

RECTIFIERS

Rectifiers of various types are manufactured for many uses. The most common type of externally mounted rectifier for automotive use is the magnesium-copper sulfide rectifier.

A rectifier mounted within the generator is the silicon-diode rectifier, as shown in figure 4-2. An advantage of the silicon-diode rectifier is its small size which permits it to be mounted internally within the casing of the alternator. The chemical composition of a diode enables current to flow through the diode in only one direction under normal conditions.

In the automotive type of alternator using silicon-diode rectifiers, six diodes are used: three positives and three negatives of the same construction, making a “full-wave bridge” rectifier.

The markings on silicon diodes vary with the alternator model and manufacturer. Some diodes are plainly marked with a (+) or (-) sign to identify their polarity (fig. 4-2). Others are marked with black or red lettering. When identifying diodes, always refer to the manufacturer’s specifications.

REGULATORS

As with the dc generator, some means must be provided to regulate the electrical output of an alternator. Normally, one of the following types of regulators is used: the electromagnetic, the transistor, or the transistorized.

The electromagnetic regulator is discussed in *Construction Mechanic 3 & 2.* A short description of the transistor and transistorized regulators follows.

The transistor regulator shown in figure 4-3 is a Delco-Remy model. It has two terminals, no moving parts, and limits the alternator voltage through the action of two transistors working together. This model performs the one function of controlling the alternator voltage to a preset value. From the wiring diagram shown in figure 4-4, the charging circuit consists of the alternator, regulator, battery, field relay, junction block, wiring, and either an ammeter or indicator light.

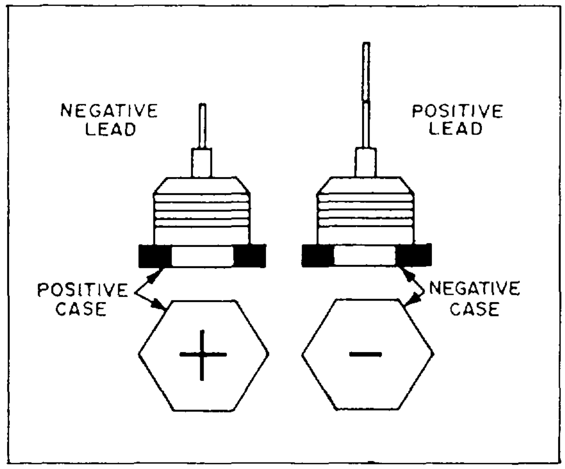


Figure 4-2.-Diodes.

Usually, you may adjust voltage internally by turning a slotted-head screw on the potentiometer which varies the connection, allowing for adjustments less than 1 volt. However, you may adjust voltage settings externally by relocating a screw in the base of the regulator. The screw contacts the series of resistors and makes a connection to ground at the point of contact.

In some transistorized regulators, a single transistor works with a conventional voltage regulator unit containing a vibrating contact point to control the alternator field current and thereby limit the alternator voltage to a preset value.

The complete charging circuit, containing a four-terminal regulator, consists of the alternator, regulator, battery, ignition switch, ammeter, and wiring,

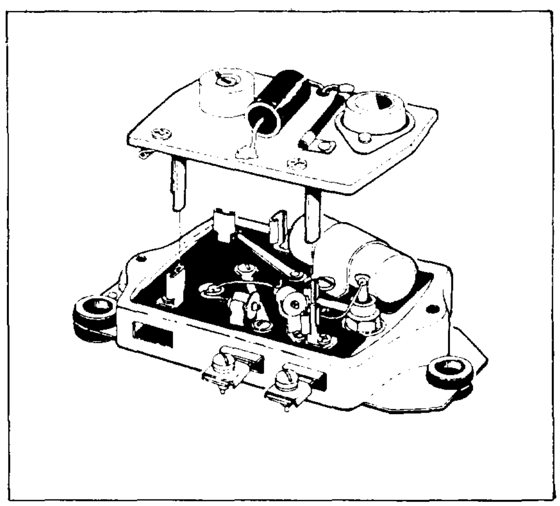


Figure 4-3.-Transistor regulator (Delco Remy).

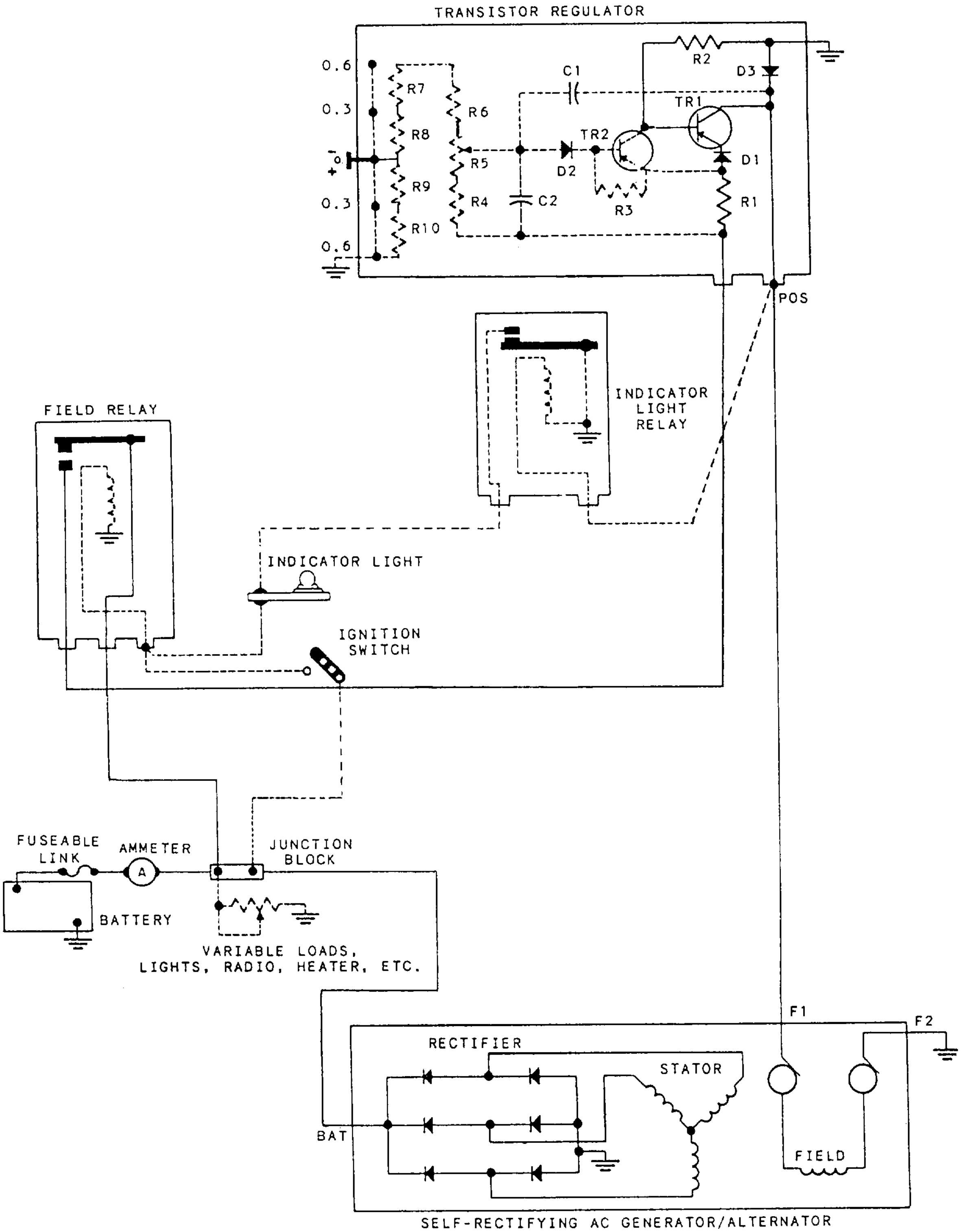


Figure 44.-Typical wiring diagram (transistor regulator).

as shown in figure 4-5. The alternator develops ac voltage in the stator windings and is rectified to a dc voltage that appears across the generator "BAT" terminal and the ground screw in the slip ring end frame.

When you service or repair a regulator, follow the manufacturer's service instructions for that specific make and model of regulator. You are not to guess about how to repair or adjust regulators.

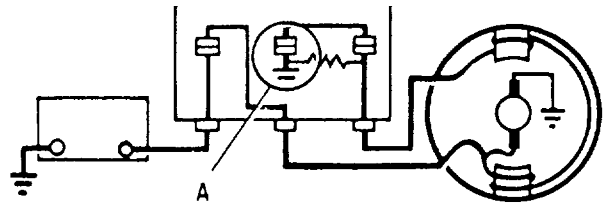


Figure 4-6.-A circuit.

TROUBLESHOOTING THE CHARGING SYSTEM WITH A VOLTAMPERE TESTER

There are two types of vehicle charging systems in use today. One system is equipped with a dc generator, and the other is equipped with an ac generator or alternator. Both systems are tested in much the same manner.

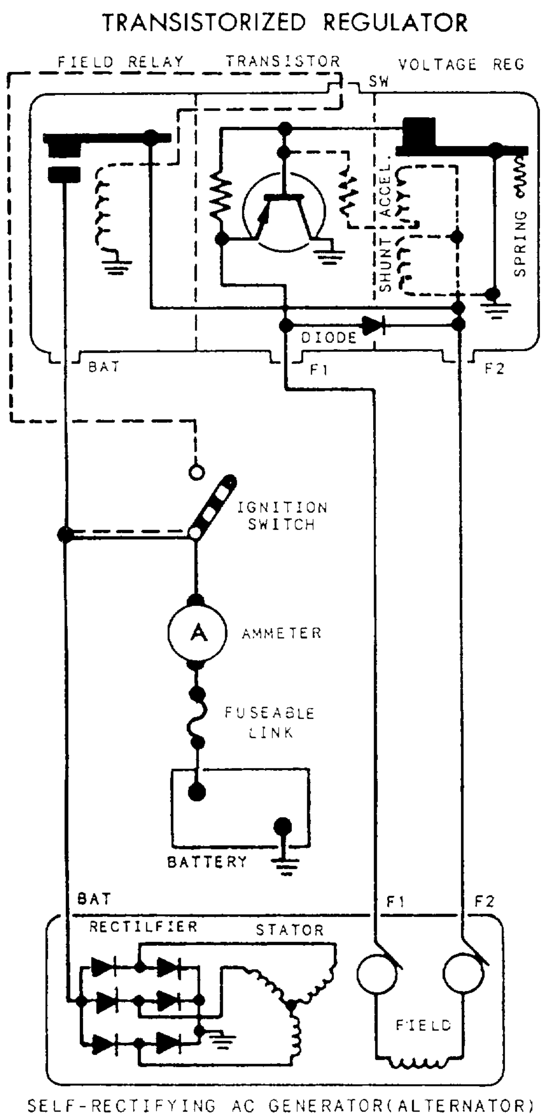


Figure 4-5.–Charging circuit (transistorized regulator).

Field circuits are commonly classified as A and B circuits. The A circuit or externally grounded field, as shown in figure 4-6, is connected to the armature terminal of the generator and is grounded outside the generator by the regulator contacts. In the B circuit shown in figure 4-7, the ground is reached internally, and the supply to the field is obtained via the armature circuit of the regulator. Most alternators and some dc generators are B circuits.

A dc generator depends upon its relatively permanent field pole piece magnetism for initial generator output. The polarity of this magnetic field determines the output polarity of the generator. A mismatched electrical system will cause early component failure. A generator with no magnetic field can produce no output. Therefore, each time a generator is repaired, installed, inoperative for a period of time, or disconnected, it must be polarized. To polarize a generator, you must pass an electric current through the field winding in the proper direction before the system is started.

To polarize an A CIRCUIT GENERATOR at the generator, ground the field and momentarily apply battery voltage to the armature terminal. To polarize at the regulator, momentarily apply a jumper lead from the armature terminal to the battery terminal. To polarize B

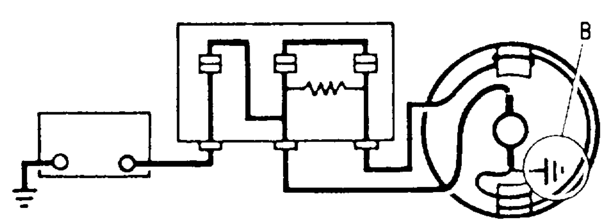


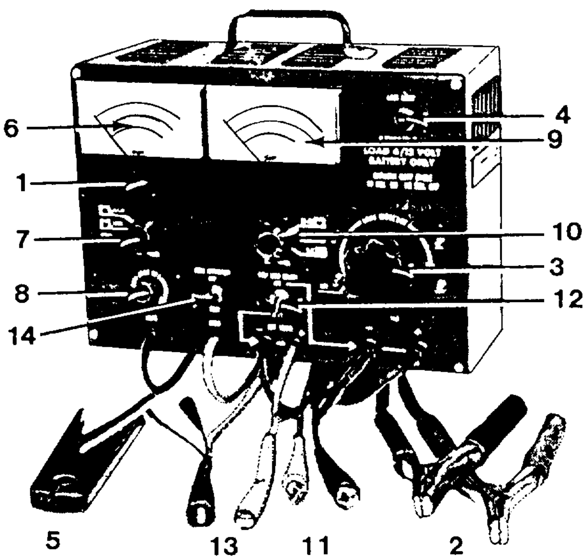
Figure 4-7.-B circuit.

CIRCUIT GENERATORS, you must disconnect the field circuit lead at the regulator and momentarily touch this lead to the regulator BATTERY terminal. Remember, alternators do not require polarization.

Various instruments can be used to locate problems in the charging system. The following sections describe troubleshooting carried out with the voltampere tester (fig. 4-8).

ALTERNATOR TEST

An alternator output test is one of the first tests to be made with the voltampere tester. To conduct this test, perform the following: disconnect the field wire at the alternator, and connect the field lead of the tester (fig. 4-9) to the field terminal of the alternator. Make sure the proper connector for the alternator being tested is used.



1. Zero adjustment
2. Load leads
3. Load increase knob
4. Load light
5. Clamp-on ampere pickup
6. Ammeter
7. Ampere range knob
8. Ampere zero set adjustment
9. Voltmeter
10. Volt range knob
11. External Volt leads
12. Volt lead selector
13. Field leads
14. Field activation switch

Figure 4-8.-Voltampere tests.

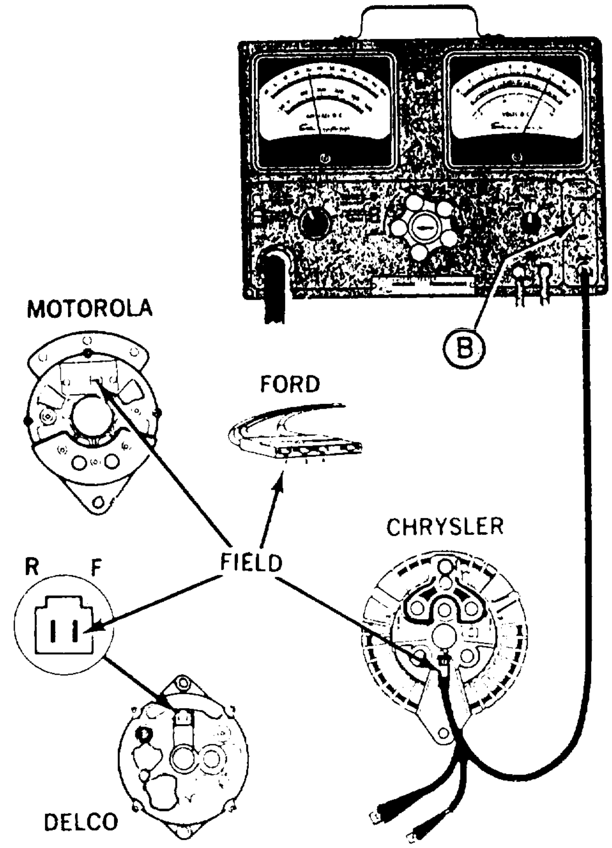


Figure 4-9.-Alternator output test.

CAUTION

Do **NOT** allow the vehicle field wire to contact ground.

Start the engine and bring the rpms up to the manufacturer's specifications. While observing the **AMMETER** scale for the highest current indication, adjust the load increase knob. The field activation switch will be held in the test position during this procedure. If the ammeter indication reads at the normal output (+ or -) 10 percent, the regulator must be replaced. When the ammeter indication reads at low or no output, the alternator must be repaired or replaced.

GENERATOR TEST

When a vehicle is equipped with an A type of field circuit generator, you may conduct a generator test by disconnecting the field at the generator and connecting the field lead of the tester (fig. 4-10) to the generator field terminal. Do NOT allow the vehicle or tester field wires to contact ground. For the B type of field circuit generator, disconnect the field wire at the regulator and connect it to the armature terminal of the regulator. Then start the vehicle engine and slowly increase speed as you observe the **AMMETER** scale for the highest ammeter reading. When the ammeter reads at the normal output, test the field lead of the wiring harness for an open circuit. If the field lead is okay, remove the regulator for testing, repair, or replacement, as required. When the ammeter reads at low output or normal voltage, the generator must be replaced or repaired. When the ammeter reads at no output or high voltage and the circuit is not fused at the regulator, remove the regulator for replacement or repair of its cutout relay. Also check the regulator ground. If the regulator is fused, bypass the fuse with a heavy

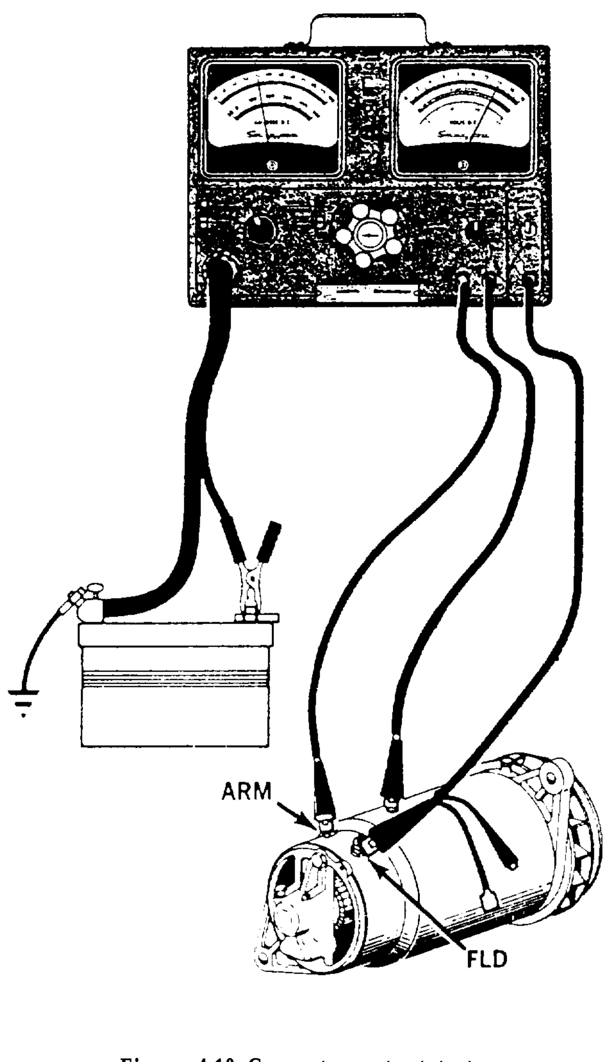


Figure 4-10.-Generator output test.

jumper and observe the ammeter for output. An output at this point in your check indicates a blown fuse.

EXCESSIVE OUTPUT TEST

To conduct an excessive output test, set the volt range knob to the correct voltage range and the volt lead selector to the EXT VOLTS position. Connect the black external volts lead to the generator armature terminal and the red external volts lead to the generator frame or a good ground. While observing the **VOLTMETER** scale for the highest voltmeter reading, start the engine and slowly increase its speed. If the voltmeter reads less than 16 volts (12-volt system) or 8 volts (6-volt system), the current limiter relay of the regulator is the reason for the high output. If the voltmeter reads more than 16 volts (12-volt system) or 8 volts (6-volt system), remove the **FIELD** wire at the regulator and observe the **AMMETER** scale. When the ammeter reading shows no output, you have a defective regulator which should be repaired or replaced. When the ammeter reading indicates a current flow, remove the field wire at the generator and observe the ammeter. If the ammeter reading then shows no output, you have a shorted field wire. Replace the field wire and connect the generator to the regulator. On the other hand, if the ammeter shows that current is flowing, then the generator has a grounded field.

Another component of the vehicle charging system you should test is the **VOLTAGE REGULATOR.** If the results of the test indicate the voltage is too high or too low, a faulty regulator voltage limiter or a high-series resistance in the charging system could be causing the trouble. Erratic or unstable voltage indicates poor circuit electrical connections, faulty regulator contacts (burned or oxidized), or damaged regulator resistors. In any case, you should proceed with a charging system circuit resistance test.

CHARGING SYSTEM CIRCUIT RESISTANCE TEST

The purpose of the charging system circuit resistance test is to determine the voltage loss between the output terminal of the generator or alternator and the insulated battery post, and between the generator or alternator housing and battery ground post, respectively. These tests can be run with any voltmeter having a small scale; that is, 3-5 volts. Any voltage loss caused by high resistance in these circuits reduces the overall charge rate and leads to eventual battery discharge.

The external volts lead is connected to the generator armature terminal, as shown in figure 4-11, when a generator is tested and to the battery terminal when an alternator is tested.

If a voltage loss exceeds the specified amount for the unit being tested, an excessive resistance is present within the charging system; that is, within the wiring harness, connections, regulator, and vehicle ammeter (if used). The excessive resistance might take the form of **LOOSE** or **CORRODED CONNECTIONS** at the output terminal of the generator or alternator, the armature terminal of the regulator, or the back of the ammeter or battery terminal of the starter solenoid battery cable connections. Excessive resistance can also be due to faulty wiring from generator to regulator, regulator to ammeter, or ammeter to starter solenoid; to burned or oxidized cutout relay contacts within the regulator; or to poor electrical connections between the generator or alternator and the engine. To isolate the point of excessive resistance, conduct a charging system insulated circuit resistance test.

CHARGING SYSTEM INSULATED CIRCUIT RESISTANCE TEST

You can conduct a charging system insulated circuit resistance test by setting the volt range selector knob to the -0.3 to 3.0 volt scale position. When you test an alternator, observe the polarity, and connect the external volts lead to the generator armature terminal or to the battery terminal. (See fig. 4-12.) Remember to reverse the external volts lead for positive ground systems. Start the engine and adjust its speed to approximately 2,000 rpm. Then adjust the load increase knob until the **AMMETER** scale indicates a current of 20 amperes for dc systems or 10 amperes for ac systems. Also observe the voltage reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications for proper charging system operation, as required by the vehicle manufacturer. If the reading is within specification, you should proceed with a charging system ground circuit resistance test.

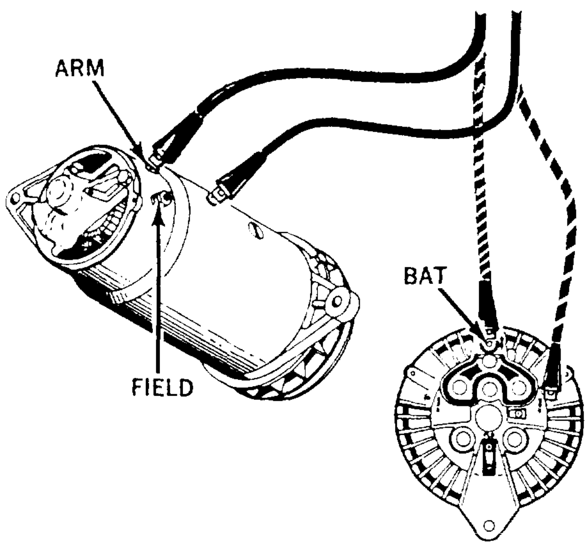


Figure 4-11.-Circuit resistance test.

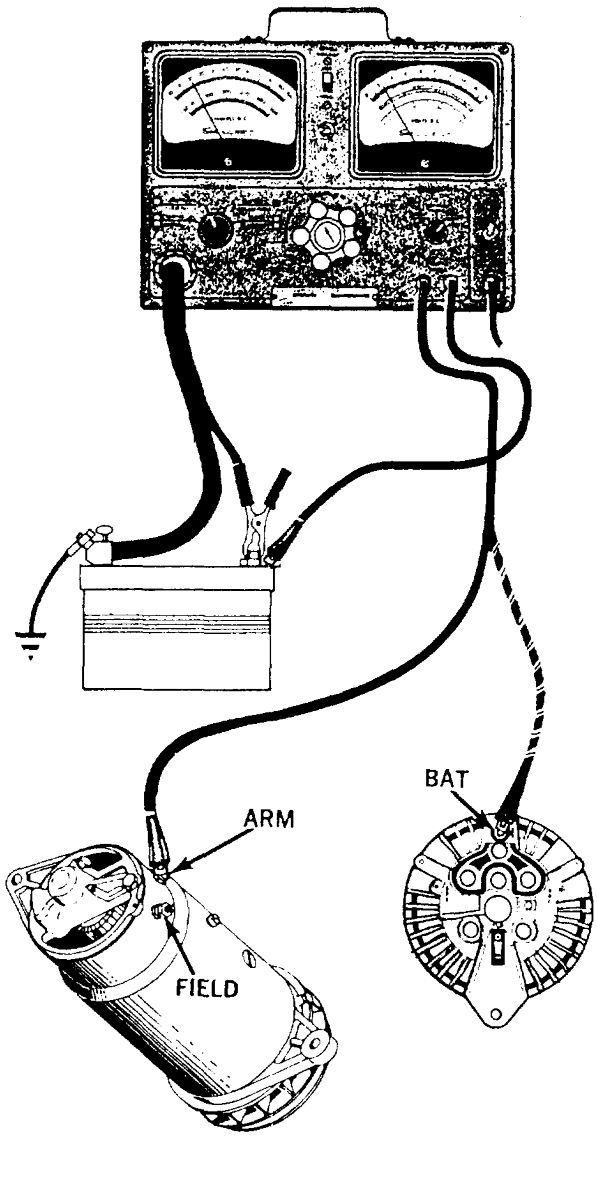


Figure 4-12.-Insulated circuit resistance test.

CHARGING SYSTEM GROUND CIRCUIT RESISTANCE TEST

When you conduct this test, observe polarity and connect the external volts lead to the generator or alternator ground terminal. (See fig. 4-13.) Then adjust the load increase knob until the ammeter scale indicates a current of 20 amperes for dc systems or 10 amperes for ac systems. Also, observe the voltage reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications for proper charging system operation, as required by the vehicle manufacturer. If the reading is within specifications, you should proceed with a regulator ground circuit resistance test.

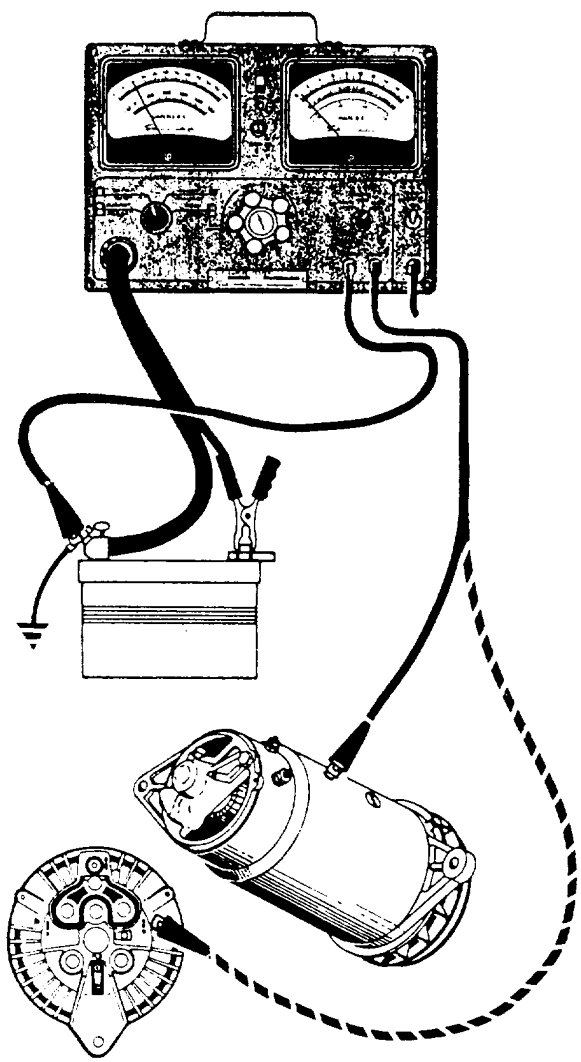


Figure 4-13.-Ground circuit resistance test.

REGULATOR GROUND CIRCUIT RESISTANCE TEST

To conduct this test, set the volt lead selector to the **INT VOLTS** position. Then, observing polarity, connect the external volts lead to the generator or alternator ground terminal and to the regulator ground terminal. (See fig. 4-14.) Adjust the load increase knob until the **AMMETER** scale indicates a current of 10 amperes. Also observe the reading on the (3-volt) **VOLTMETER** scale and compare it with the specifications. If the voltmeter reading exceeds 0.1 volt, excessive resistance is in the ground circuit between the regulator and the generator or alternator. Check the regulator ground system for loose mounting bolts or a damaged ground strap.

BATTERY DRAIN TEST

The purpose of this testis to determine if a discharge current is flowing when all accessories and lights are turned off. Any discharge at this time would indicate the presence of partially shorted or grounded wires,

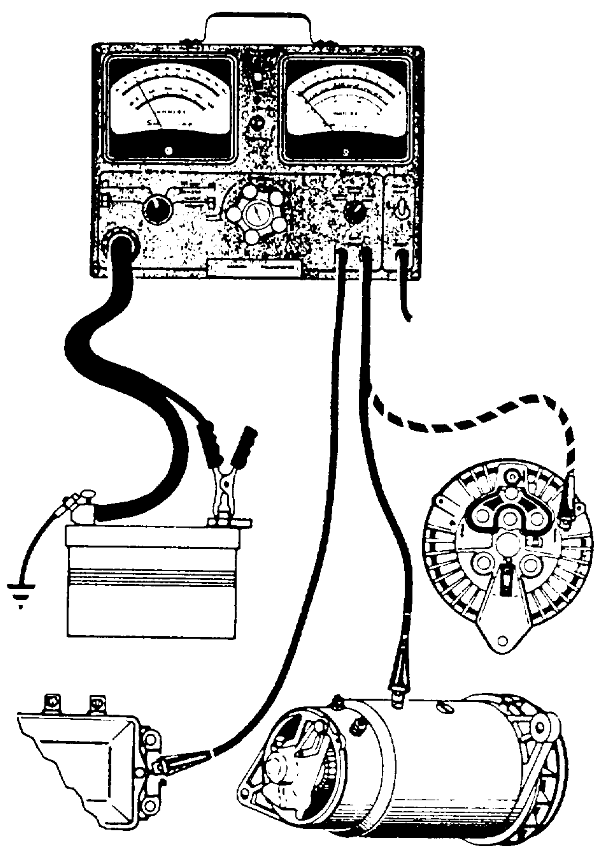


Figure 4-14.-Regulator ground circuit resistance test.

defective switches, or accessories. This condition of discharge leads to a frequently rundown battery and starting failure complaints. Turn the vehicle ignition switch to **OFF.** Lights and accessories must be **OFF** and doors closed. Observe the **AMMETER** scale. If the ammeter scale reads zero, there are no short or grounded circuit paths for current, in which case the electrical system is okay and all tests are completed. If the ammeter scale reads other than zero, an electrical short or grounded circuit exists if all the vehicle circuits are turned **OFF.** The short or grounded circuit may be found by isolating each circuit, one at a time, until the ammeter reads zero. The last circuit isolated, as the ammeter returned to zero, is the defective one. Many circuits can be isolated by removing the circuit& from the fuse panel.

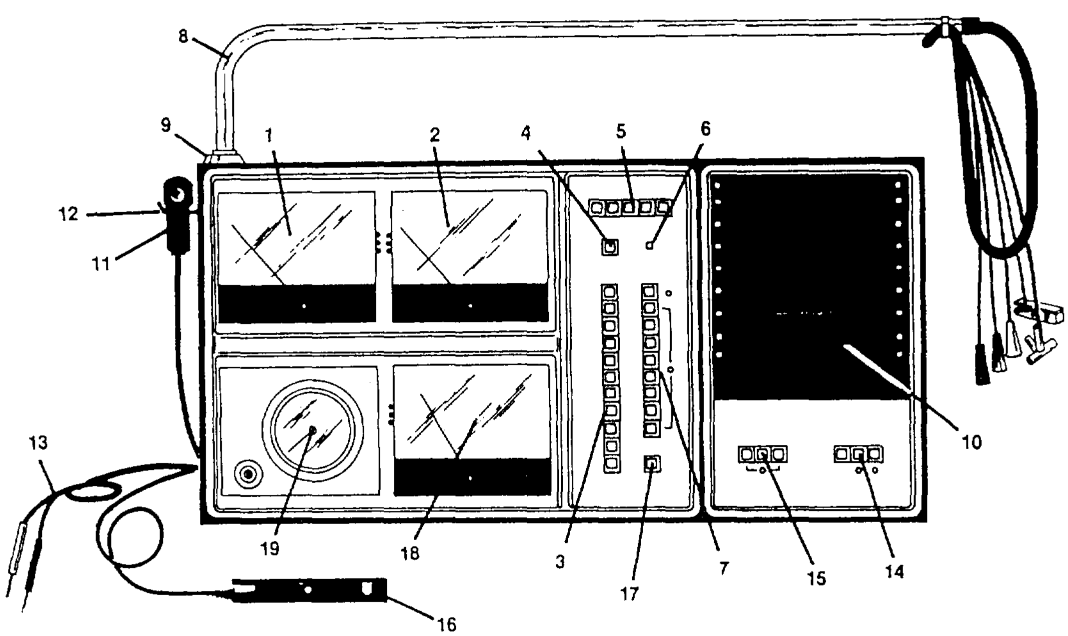
NOTE

When you finish the test, shut the engine down and turn the ignition switch to the **OFF** position before disconnecting any test leads.

Reconnect the ground cable to the ground post of the battery, and make sure all vehicle wires disconnected during the testing are again securely and properly connected.

TROUBLESHOOTING THE ALTERNATOR USING THE ENGINE ANALYZER SCREEN

Normally, when an engine analyzer (fig. 4-15) is available for use, it is in the electrical shop. The following information explains how to use the analyzer to test alternators. In considering this information, remember the following points: (1) the example shown is one of several manufactured, (2) the analyzer will do much more than just test alternators, and (3) **ALWAYS** refer to the manufacturer's manual of the analyzer and the unit being tested before making any connections.



1. Voltmeter-CO
2. Tachometer-ohm
3. Test selector
4. Special ignition
5. Engine selector
6. Primary load "ON" indicator
7. Cylinder selector
8. Boom
9. Boom collar
10. Screen-viewing area
11. Timing light
12. Hanger
13. Ohm leads and special test
14. Sweep selector
15. Pattern selector
16. Current probe
17. On-off
18. Timing-amp-dwell
19. Vacuum gauge

Figure 4-15.-Engine analyzer.

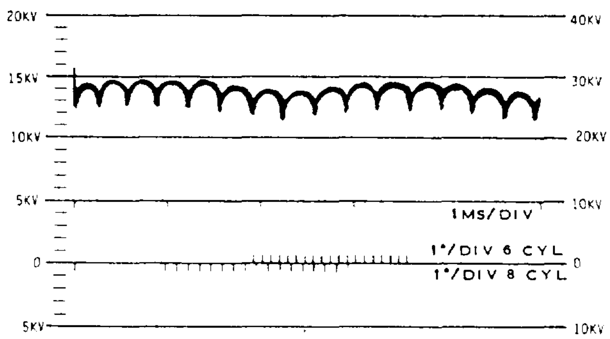


Figure 4-16.-Ripple pattern of alternator output.

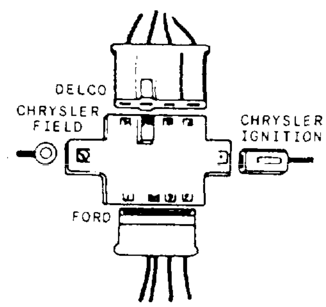


Figure 4-18.–Bypass adapter.

CHARGING CIRCUIT DIODES

When an alternator fully produces, each of its diodes conducts an equal share of the current. This condition is indicated by a ripple pattern that appears on the screen of the engine analyzer. (See fig. 4-16.) But a single nonconducting diode places a strain on the charging circuit which causes a decrease in the output of the alternator. Whereas an ammeter or voltmeter may not detect this strain, the analyzer can do so easily. The strain brought on by an open field condition, for example, will stop the alternator output ripple entirely. See the screen display of figure 4-17.

A likely result of decreased alternator output is an undercharged battery, and without a fully charged battery, there may not be enough current available to start the engine or meet the demands of the electrical circuits. When a good battery cannot be fully charged, the fault is usually in the alternator or voltage regulator. The engine analyzer can help you determine which is at fault. However, the regulator has to be bypassed altogether and battery voltage applied to the field terminal of the alternator. Not all alternators can be full fielded. Refer to the manufacturer's fieldtest procedure.

BYPASS PROCEDURE

The first step in the procedure for bypassing the voltage regulator is for you to turn **OFF** the engine. Next, disconnect the regulator and place a jumper wire between the positive (+) battery terminal and the field terminal of the alternator. You can also use the bypass adapter hooked up as shown in figure 4-18. Again start the engine and slowly increase its speed until the rated alternator output is reached. **DO NOT RUN THE ENGINE FOR MORE THAN 20 SECONDS.**

If the ripple pattern now appears on the screen of the engine analyzer, the regulator is faulty. No change in the screen pattern means the alternator or output wiring is at fault. Stop the engine, disconnect the jumper wire or bypass adapter, and reconnect the voltage regulator.

OPEN AND SHORTED DIODES

A shorted diode or shorted winding will usually burn itself open. The pattern on the screen will show a shorted diode (fig. 4-19) or open diode (fig. 4-20). Notice the similarity in the patterns. At any rate, the alternator will require service or replacement even

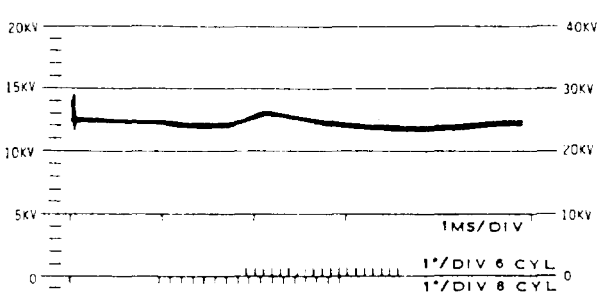


Figure 4-17.-Open file stops the ripple.

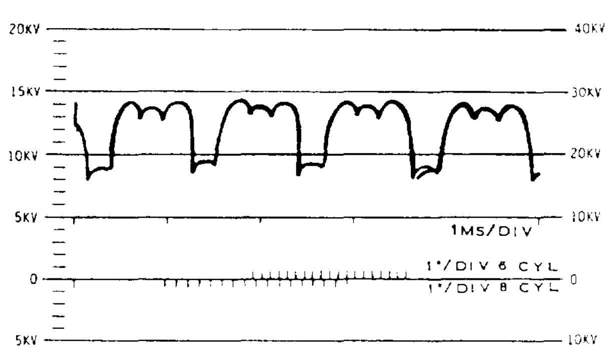


Figure 4-19.-Shorted diode pattern.

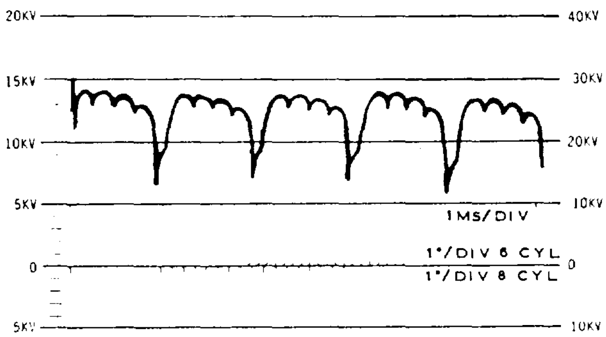


Figure 4-20.-Open diode pattern.

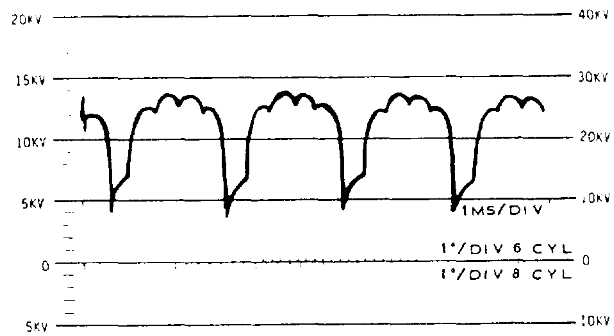


Figure 4-22.-Shorted winding pattern.

though both output current and voltage regulation appear to be acceptable. As a general rule, a shorted diode affects the output more than an open diode does. It not only reduces the output, but it also opposes the next pulse by allowing the current to flow back through the winding containing the shorted diode.

WEAK DIODES

As you can see from the screen pattern in figure 4-21, there is no interruption in the rectification of the diodes. However, there is a high and low peak every sixth pulse, indicating that the output of one diode is low and that it may be deteriorating (high resistance). This pattern may also occur due to a shorted winding since the number of windings determines the amount of output as well as the condition (resistance) of the diodes.

SHORTED WINDINGS

Depending on the location of the short, shorted windings and shorted diodes produce similar screen patterns because the defect is the same. Compare figures 4-19 and 4-22. The alternator test screen patterns shown arc for diagnosis only; therefore, the alternator must be removed to locate the defective internal component. Now, it is a matter of verifying the problem with simple ohmmeter tests or by replacing defective components.

TROUBLESHOOTING THE CRANKING SYSTEM USING THE BATTERY STARTER TEST

To determine whether a battery is fit for service, you can perform a cranking system test with a battery starter tester, model **BST,** as shown in figure 4-23. This tester, made by Sun Electric Corporation, is designed to test only batteries and starting systems of vehicles using 6-, 12-, 24-, or 32-volt systems.

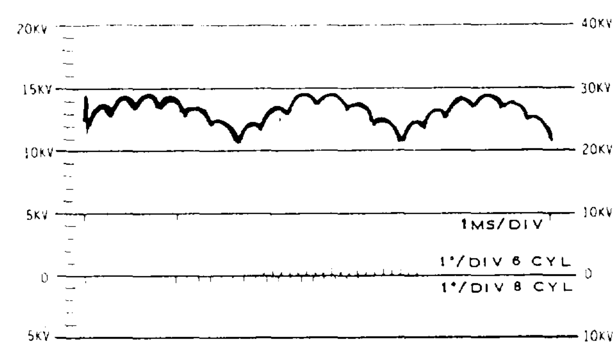


Figure 4-21.-Poor diode pattern.

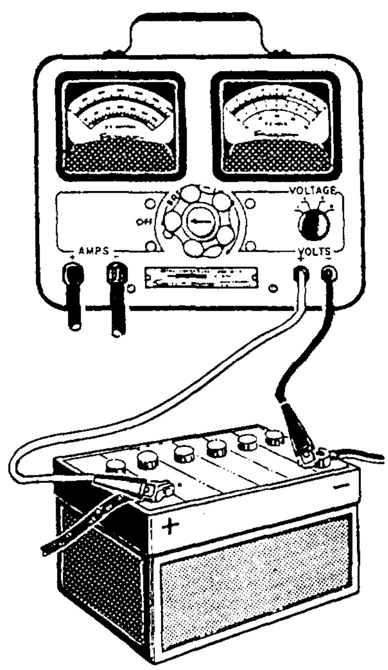


Figure 4-23.-Cranking voltage test.

CRANKING VOLTAGE TEST

When you test the cranking voltage in a 6-, 12-, or 24-volt series system, connect the voltmeter leads of the (ester, as shown in figure 4-23. Observe the polarity as you make the connections. Then turn the voltmeter selector switch to 8 volts for a 6-volt system, 16 volts for a 12-volt system, or 40 volts for a 24-volt system. When a vehicle is equipped with a 24-volt series parallel system, the voltmeter leads arc attached to the two terminals on the starting motor. Before cranking the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting while testing. While cranking, observe both the voltmeter reading and cranking speed. The starter should crank the engine evenly, and at a good rate of speed, with a voltmeter reading as follows **(UNLESS OTHERWISE SPECIFIED):**

- 4.8 volts or more for a 6-volt system
- 9.6 volts or more for a 12-volt system
- 18 volts or more for a 24-volt system

When the cranking voltage and cranking speed are good, it is reasonably safe for you to assume that the starting motor and starting circuits are in order. If the cranking voltage is lower than specified, test the battery capacity, starter circuits, and starter cranking current. However, if the cranking voltage is high but the starter action is sluggish, check for starting circuit resistance, as outlined in the circuit resistance tests given later in this chapter.

Provided the engine cranking load is normal, excessive starting motor current indicates trouble in the starting circuit. However, increased current is normal on new or newly overhauled engines or where the cranking load is above normal.

To check an excessive starting motor current, you can perform a starting motor current draw test of the 6-, 12-, or 24-volt series system.

STARTING MOTOR CURRENT DRAW TEST

To conduct this test, turn the battery starter tester control knob to the **OFF** position. Then turn the voltmeter selector switch to 8 volts for a 6-volt system or 16 volts for a 12-volt system. When a vehicle is equipped with a 24-volt series system the voltmeter selector switch is turned to 16 volts if 12-volt batteries are used or to 8 volts if 6-volt batteries are used. On a 24-volt series system, connect the voltmeter leads across one 6- or 12-volt battery **ONLY.** Connect the **VOLTMETER** leads of the tester, as shown in figure 4-24.

Before you crank the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting during testing. While cranking, note the exact reading on the voltmeter. After cranking, turn the control knob of the battery tester clockwise until the voltmeter again reads exactly as it did during cranking. The test **AMMETER** should indicate the starting motor current within the normal range of the vehicle being tested, as determined from the manufacturer's specifications.

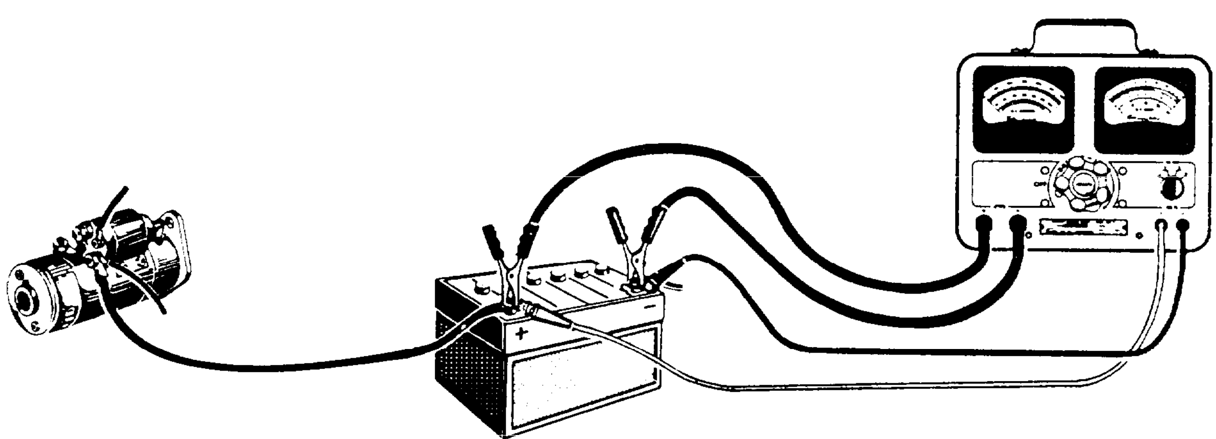


Figure 4-24.-Starting motor current draw test.

However, if the test indicates normal starter current but low cranking speed, check the resistance in the starting circuit. If high starter current is encountered during the test, starting circuit trouble is indicated. In the case of low starter current, accompanied by low cranking speed, or complete failure of the engine to crank, look for resistance within the starting circuit wiring or starting motor.

STARTER INSULATED CIRCUIT RESISTANCE TEST (CABLES AND SWITCHES)

To conduct the starter insulated circuit resistance test on a 6-, 12-, or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in views A, B, and C of figure 4-25, for the type of current being tested, and observe the polarity as you make the connections. The voltmeter will read off-scale

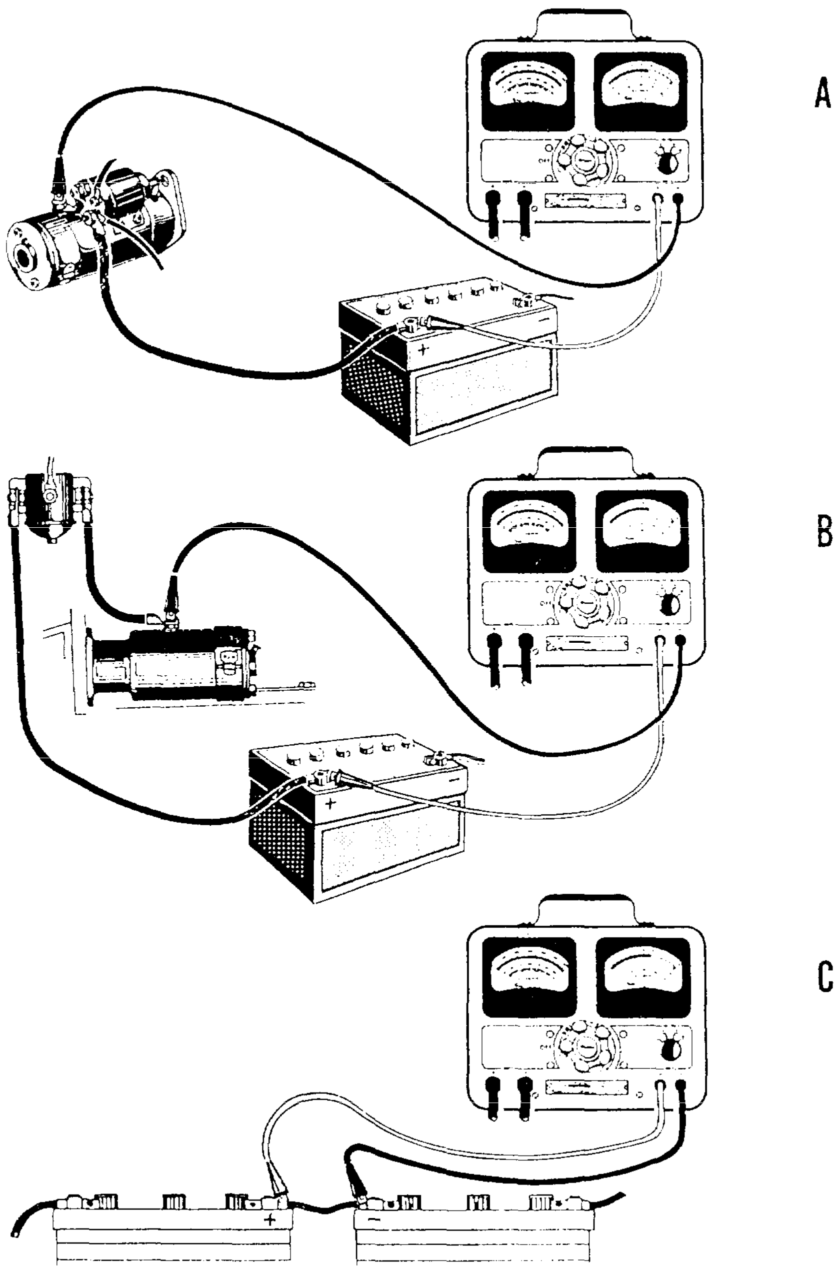


Figure 4-25.-Starter insulated circuit resistance test.

to the right until the engine is cranked. The voltmeter lead clips must be in good contact with the battery posts and the starter terminal. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper from the secondary terminal of the coil to ground to prevent the engine from starting while it is being tested. While cranking the engine, observe the voltmeter reading which should be within the manufacturer's specifications. Unless otherwise specified by the manufacturer, the voltage loss in each of the circuits shown in views A, B, and C should not exceed the value given.

When you test a 6-volt system, the completed circuit shown in view A allows a 0.2 volt loss and that of view B, allows a 0.3 volt loss. When you test a 12-volt system, the completed circuit shown in view A allows a 0.4 volt loss and that of view B, a 0.3 volt loss, and that of view C, a 0.1 volt loss. If testing a 24- or 32-volt system, refer to the manufacturer's specifications. If the voltmeter reading is more than specified for the type of system being tested, high resistance is indicated in the cables, switches, or connections. Repeat the test with the voltmeter connected to each cable, switch, and connector of the circuit. The maximum readings taken across these parts should not exceed the values listed below.

	6-Volt System	12-Volt System
Each cable	0.1 volt	0.2 volt
Each switch	0.1 volt	0.1 volt
Each connector	0.0 volt	0.0 volt

STARTER GROUND CIRCUIT RESISTANCE TEST

Excessive resistance in the ground circuit of the starting system can cause sluggish cranking action or failure to crank. It can also seriously interfere with the operations of the electrical circuits using the same ground.

To conduct the starter ground circuit resistance test on a 6-, 12-, or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in figure 4-26, and observe the polarity as you make the connections. Be sure the voltmeter lead clip at the battery contacts the battery post and not the battery cable clamp. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper lead from the secondary terminal of the coil to ground to prevent the engine from starting while it is being tested. While cranking the engine, observe the voltmeter reading. Unless otherwise specified by the manufacturer's

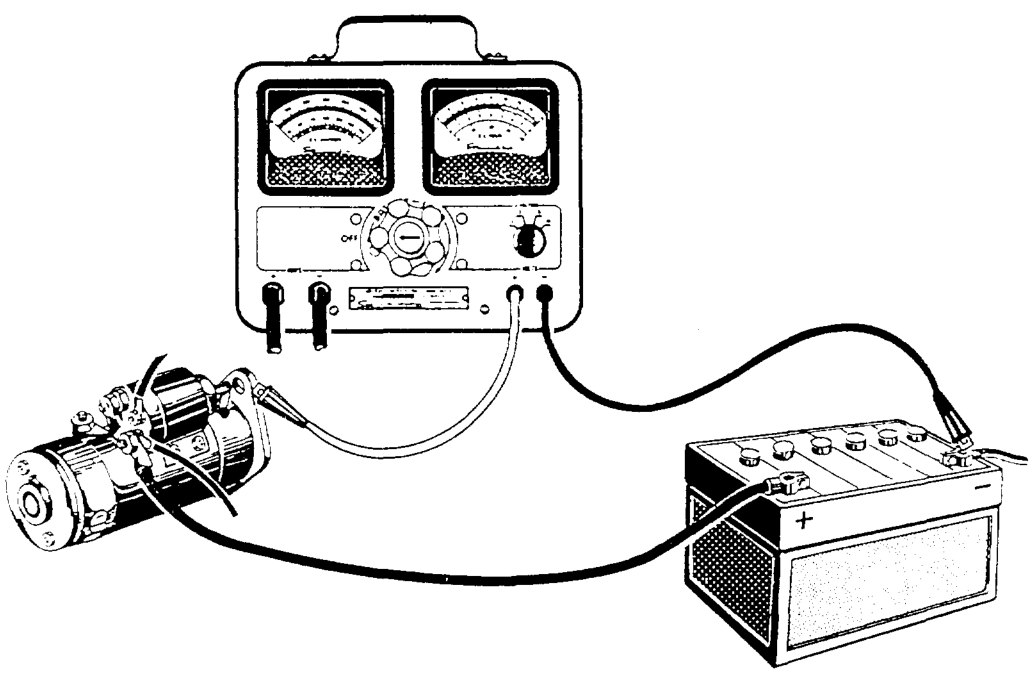


Figure 4-26.-Starter ground circuit resistance test.

specifications, this reading should not exceed a 0.2 volt loss. A reading of more than 0.2 volt loss usually indicates a loose, dirty or corroded connection, or ground cables that are too small to carry the current. To locate the point of excessive resistance, apply the voltmeter leads across each connection and cable, in turn, and take the readings with the starting motor in operation. These readings should not exceed 0.1 volt loss on short ground cables and should be zero across each connection. Long ground cables may have slightly more than 0.2 volt loss.

SOLENOID SWITCH CIRCUIT RESISTANCE TEST

High resistance in the solenoid switch circuit reduces the current flow through the solenoid windings and causes the solenoid to function improperly or not at all. Improper action of the solenoid switch, in most cases, results in burning of the main switch contacts which reduces current flow in the starter motor circuit.

To conduct the solenoid switch circuit resistance test on a 6-, 12- or 24-volt series system, perform the following:

Connect the **VOLTMETER** leads of the tester, as shown in figure 4-27, and observe the polarity as you make the connections. Be sure the voltmeter lead clip at the solenoid contacts the switch terminal–not the solenoid wire end. Now, turn the voltmeter selector switch to the No. 4 **VOLT** position. Before cranking the engine with the ignition switch **ON,** connect a jumper lead from the secondary terminal of the coil to ground to prevent the engine from starting during the test. While cranking the engine, observe the voltmeter reading. This reading, unless otherwise specified by the manufacturer's specifications, should not exceed a 0.5 volt loss. A reading of more than a 0.5 volt loss usually indicates excessive resistance. However, on certain vehicles, experience may show that a slightly higher voltage loss is normal. To isolate the point of high resistance, apply the voltmeter leads across each part of the circuit, in turn, taking readings with the starting motor in operation. A reading of more than 0.1 volt loss across any one wire or switch usually indicates trouble. If high readings are obtained across the neutral safety switch used on automatic transmission equipped vehicles, check the adjustments of the switch as outlined in the manufacturer's manual. Make sure all vehicle wires disconnected during the tests are reconnected securely and properly at the conclusion of the tests.

IGNITION SYSTEMS

The treatment of ignition systems given in *Construction Mechanic 3 & 2,* NAVEDTRA 10644, mainly deals with the operating principles of a conventional automotive ignition system. The treatment

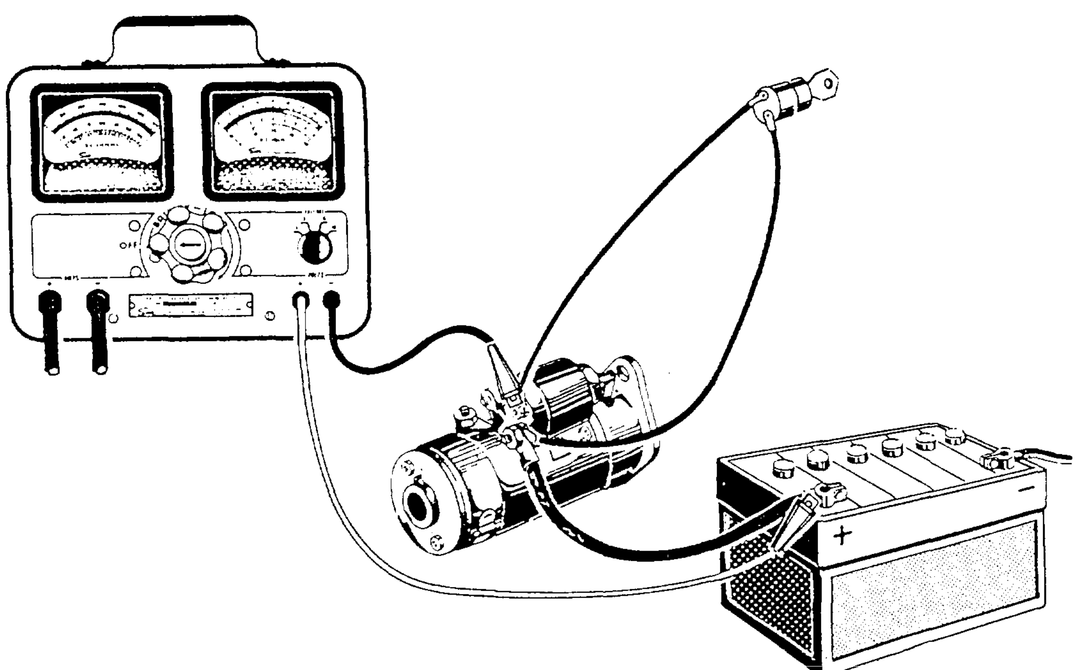


Figure 4-27.-Solenoid switch circuit resistance test.

here continues with the basic types of transistor ignition systems (breaker-point and magnetic-pulse), the capacitor discharge ignition system, the Chrysler electronic ignition system, the Delco-Remy unitized ignition system, and the Ford computerized ignition system.

TRANSISTOR IGNITION SYSTEM (BREAKER-POINT TYPE)

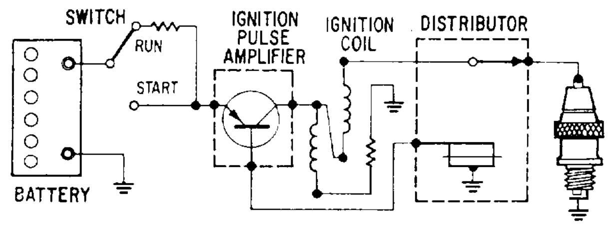


Figure 4-29.-Transistor ignition system (breaker-point type).

The breaker-point type of transistor ignition system was developed to replace the standard or conventional ignition system. To obtain the maximum power and speed that this engine can produce, you must install an ignition system that outperforms the conventional one. Electronic type of ignition systems provide a hotter, more uniform spark at a more precise interval. This promotes more efficient burning of the air/fuel mixture in the combustion chamber, producing less exhaust emissions, and resulting in better engine performance and increased mileage. The increased reliability of electronic ignition allows less frequent maintenance by increasing parts life. At high speeds, the breaker points of a conventional ignition system cannot handle the increased current flowing across them without pitting too much. Also, the dwell angle of the breaker points is too small for complete saturation of the ignition coil. The transistorized ignition system takes care of both drawbacks.

By comparing figures 4-28 and 4-29, you can see how the transistor ignition system differs from the conventional. When the breaker points are connected to the transistor, as shown in figure 4-29, it nearly eliminates arcing across them since the current flow is small (about one-half ampere). However, the current flow in the primary windings of the coil is about 6 amperes. This amount is enough to saturate the coil completely at high engine speeds, and results in a higher output to the secondary circuit. Therefore, the transistor ignition system is superior to the conventional system at high engine speeds because there is less arcing across the breaker points and higher and steadier voltage in the secondary circuit.

TRANSISTOR IGNITION SYSTEM (MAGNETIC-PULSE TYPE)

The drawbacks of a conventional ignition system operating at high engine speeds can also be overcome with the magnetic-pulse type of transistor ignition system (fig. 4-30). Notice that a magnetic pulse distributor, which resembles a conventional distributor, is used instead of a breaker-point type of distributor. An iron timer core in this distributor replaces the standard breaker cam. The timer core has equally spaced projections (one for each cylinder of the engine) and rotates inside a magnetic pickup assembly. This pickup assembly replaces the breaker plate assembly of the conventional distributor. Since there are no breaker points and there is no condenser, there can be no arcing across them. Capacitors in this system are for noise suppression. This overcomes one of the drawbacks already mentioned. The other drawback is overcome by controlling the amount of current that flows through the primary windings of the ignition coil and to ground. Transistors in the ignition pulse amplifier do the controlling. Another feature of this transistor ignition system is its coil, which has fewer and heavier primary windings and a higher turns ratio of primary to secondary windings than the conventional coil. Controlling the current flow and using a special coil

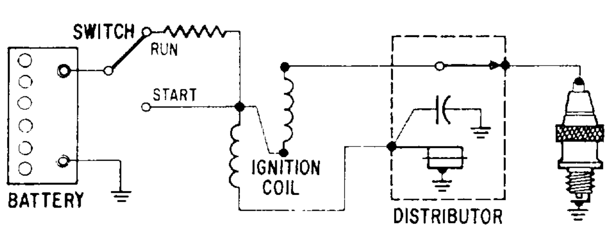


Figure 4-28.-Conventional ignition system.

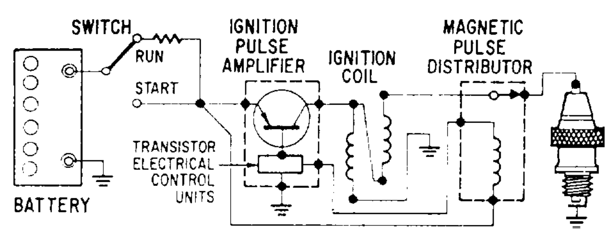


Figure 4-30.-Magnetic-pulse type transistor ignition system.

produce the desired voltage in the secondary circuit at high engine speeds.

CAPACITOR DISCHARGE IGNITION SYSTEM

The capacitor discharge (CD) ignition system is also superior to the conventional ignition system. Like the magnetic- pulse transistor ignition system, the CD system has a special ignition coil, a transistorized pulse amplifier, and a magnetic puke distributor. Unlike the magnetic-pulse transistor ignition system, the CD system has a high-voltage condenser connected across the primary windings of the coil. The input to the coil is constant and assures complete saturation of the coil which results in the desired secondary voltage output at high engine speeds.

ELECTRONIC IGNITION SYSTEM (CHRYSLER)

Like the magnetic-pulse transistor ignition system, Chrysler's electronic ignition system is breakerless; that is, there are no breaker points and there is no condenser. (See fig. 4-31.)

The Chrysler electronic ignition system in figure 4-32 consists of a battery, an ignition switch, a dual ballast resistor, a special ignition coil, an electronic control unit, and a special pulse-sending distributor.

Instead of the cam and rubbing block of the conventional ignition system, the Chrysler electronic system uses a magnetic pickup coil and a rotating reluctor (fig. 4-33). As the teeth of the reluctor pass the magnet of the pickup coil, a voltage pulse is induced in the pickup coil which is a signal for the module to "interrupt" the primary coil current. The magnetic field in the ignition coil collapses and induces a high voltage into The secondary winding which fires the spark plugs.

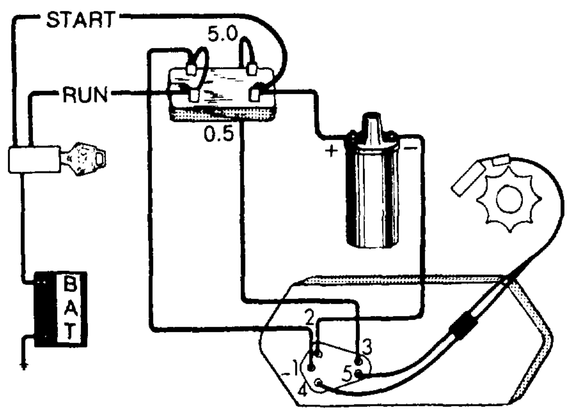


Figure 4-32.-Electronic ignition system.

The electronic module is a solid-state device that interrupts the primary coil current when signaled and self-starts the primary current after a predetermined time lapse. A compensating ballast resistor (0.5 ohms typical) is used in series with the ignition coil and battery circuit. The compensating ballast resistor maintains a constant primary current with changes in engine speed. During starting or cranking, the compensating ballast resistor is bypassed, supplying full-battery voltage to the ignition coil. The auxiliary ballast resistor (5.0 ohms typical) limits the current to the electronic module.

On this system, you adjust the air gap by aligning one reluctor tooth with the pickup coil tooth. After loosening the holding screw, use a nonmagnetic feeler gauge of the correct size to obtain the proper air gap between the reluctor and the pickup coil. Check the setting for proper clearance at the reluctor tooth with a nonmagnetic feeler gauge that is 0.002 inch larger than the manufacturer's specification.

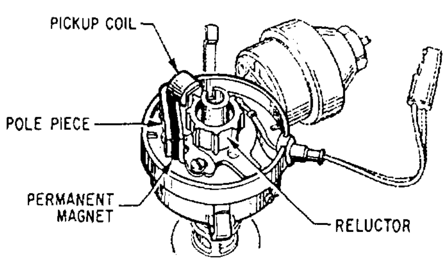


Figure 4-31.-Electronic ignition distributor components.

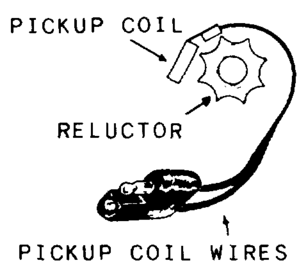


Figure 4-33.-Electronic pickup and reluctor.

CAUTION

Do not force the feeler gauge into the air gap. This should be a go-no-go tolerance.

Unless the distributor sensors depend directly on the electronic module for operation, as they do in the American Motors Breakerless Inductive Discharge System (BID), the engine analyzer may be used to check the magnetic pickup coil. To check the coil, operate the analyzer in the self-sweep mode and disconnect the pickup from the harness.

CAUTION

NEVER connect the analyzer to a distributor without first referring to the operator's manual for the correct procedure.

Connect the red and black test probes across the pickup coil wires and crank the engine as you observe the screen display. The screen trace should oscillate above and below the zero line if the pickup is good.

ELECTRONIC LEAN BURN SYSTEM/ELECTRONIC SPARK CONTROL (CHRYSLER)

Since current model engines burn a leaner fuel air mixture within the cylinders, a special means of igniting this mixture is required; for example, the electronic lean burn system (fig. 4-34). It consists of a solid-state spark control computer, various engine sensors, and a specially calibrated carburetor. Also, the distributor provides centrifugal spark advance only (no vacuum

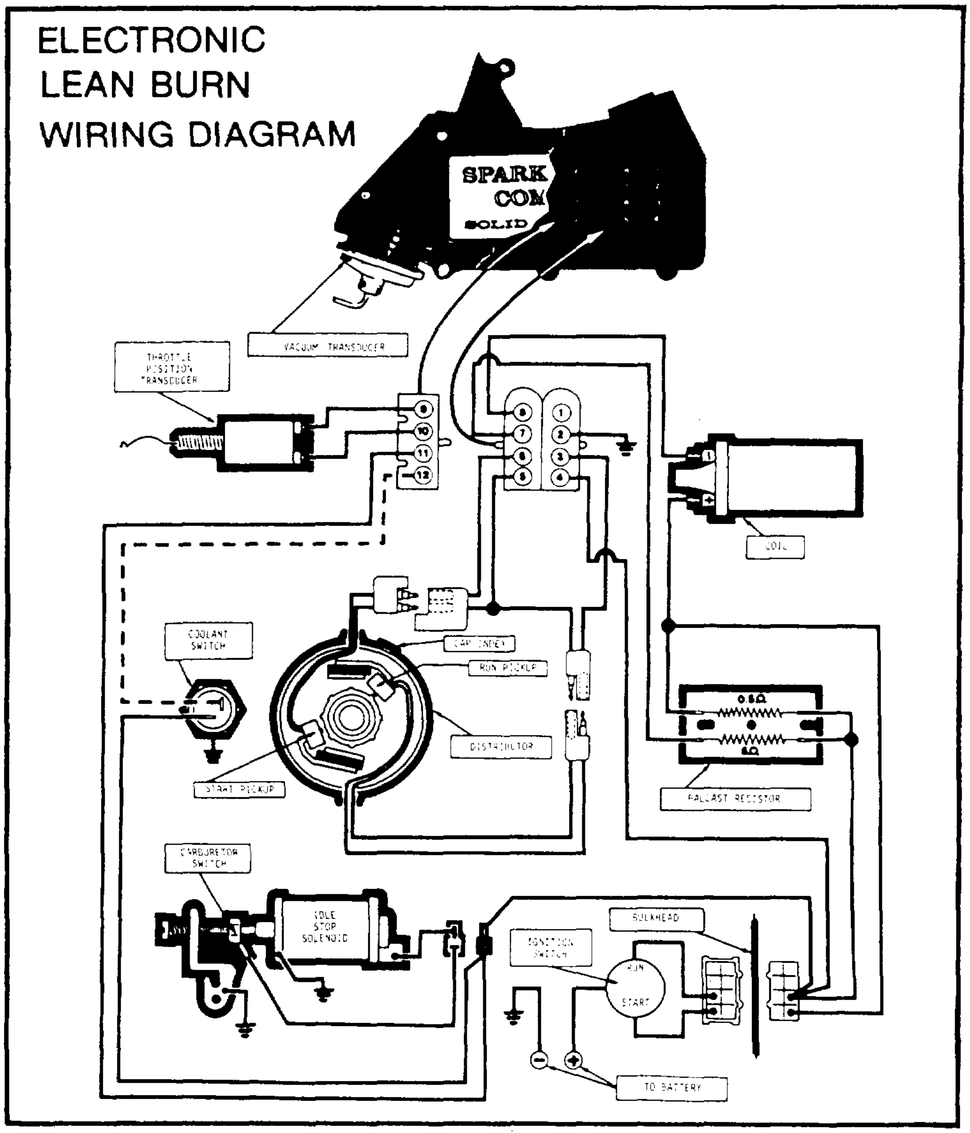


Figure 4-34.-Lean burn ignition system.

advance). Located in the distributor are two pickup coils (fig. 4-35), **NOT** found in 1978-1979 models. One coil operates during starting, whereas the other coil operates when the engine is running. The starting pickup is easily identified; its distributor connection is larger.

The computer selects either the start or run coil, not the ignition switch. The spark advance is controlled primarily by the spark control computer which receives its signals from the following engine sensors:

1. Coolant Temperature Switch (on the water pump housing) signals that the engine temperature is below 150°.

2. Air Temperature Switch (inside the computer, but not used after 1979) senses the temperature of the incoming fresh air which controls the throttle position advance.

3. Carburetor Switch (on the right side of the carburetor) tells the computer whether the engine is at idle or off idle.

4. Vacuum Transducer (on the computer) signals the computer for more spark advance with higher vacuum and less spark advance with lower vacuum. The computer responds over a period of time rather than suddenly, using a timed countdown delay.

5. Throttle Position Transducer (on the carburetor but eliminated in 1980) signals the computer to advance by indicating the new throttle plate position and the rate of change.

UNIT IGNITION SYSTEM (DELCO-REMY)

This unitized ignition system by Delco-Remy is another breakerless ignition system. It is called unitized because the entire system is built into one unit, the distributor. This distributor contains the ignition coil, the secondary wiring harness and cap, shell, rotor, vacuum advance unit, pickup coil, timer core (which replaces the cam), and electronic module. The distributor operates on an electronically amplified pulse. Vacuum spark advance and mechanical spark advance are applied in the usual way. The moving parts of this system induce a voltage that signals the electronic module to interrupt the primary circuit. The desired voltage is then induced in the secondary windings of the ignition coil and directed to the proper sparkplug by the rotor and the secondary wiring harness and cap.

HIGH-ENERGY IGNITION SYSTEM (DELCO-REMY)

The Delco-Remy High-Energy Ignition (HEI) System is a breakerless, pulse-triggered, transistor-controlled, inductive discharge ignition system. The HEI system and the older Unit Ignition System differ in that the HEI system is a full 12-volt system. The Unit Ignition System also incorporates a resistance wire to limit the voltage to the coil, except during starter motor operation.

The cam and point rubbing block of the conventional ignition system are replaced by the timer core, pickup coil, and electronic module in the HEI system (fig. 4-36). A timer core rotates inside the pickup

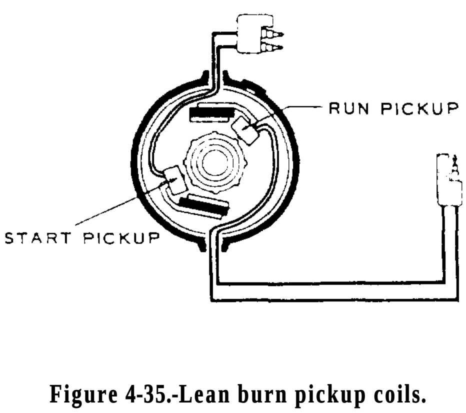


Figure 4-35.-Lean burn pickup coils.

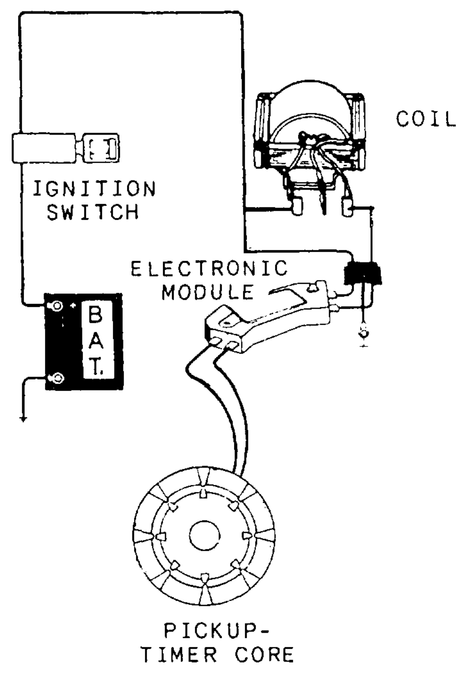


Figure 4-36.-High-energy ignition system.

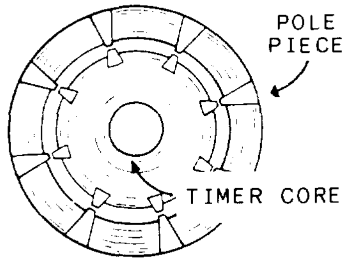


Figure 4-37.-High-energy timer and pole pieces.

coil pole piece (fig. 4-37). When the timer core teeth align with the pole piece, a voltage pulse is induced in the pickup winding. This pulse signals the module to activate the primary coil current, inducting high voltage in the secondary windings and ultimately firing the spark plug. The module automatically y controls the dwell period, stretching it as engine speed increases. Therefore, the primary current reaches its maximum strength at high engine speeds and reduces the chances of high-speed misfire. The secondary coil energy (35,000 volts) is greater than in conventional ignition systems which allows increased spark duration. The longer spark duration of the HEI system is instrumental in firing lean and exhaust gas recirculation (EGR) diluted fuel/air mixtures. The condenser within the HEI distributor is provided for noise suppression only.

COMPUTERIZED IGNITION SYSTEM

Today, minicomputers are being used to control many modern automotive systems. One example is Ford's electronic engine control system (EEC). This system consists of an electronic control assembly (ECA), seven monitoring sensors, a Dura Spark II ignition module and coil, a special distributor assembly, and an EGR system designed to operate on air pressure.

The ECA is a solid-state microcomputer consisting of a processor and a calibration assembly. Refer to figure 4-38 while studying the operation of this system. The processor continuously receives inputs from the seven sensors and converts them into usable information that is received by the calculating section of the computer. The processor assembly also performs ignition timing, does Thermactor and EGR flow calculations, processes this information, and sends out signals to the ignition module and control solenoids to adjust the timing and flow of the systems accordingly. The calibration assembly contains the memory and programming for the processor.

Processor inputs come from sensors that monitor manifold pressure, barometric pressure, engine coolant temperature, inlet air temperature, crankshaft position, throttle position, and EGR valve position.

Manifold Absolute Pressure Sensor

This sensor detects changes in intake manifold pressure that are caused by variances in engine speed, engine load, or atmospheric pressure.

Barometric Pressure Sensor

Barometric pressure is monitored by a sensor mounted on the fire wall. Measurements taken are

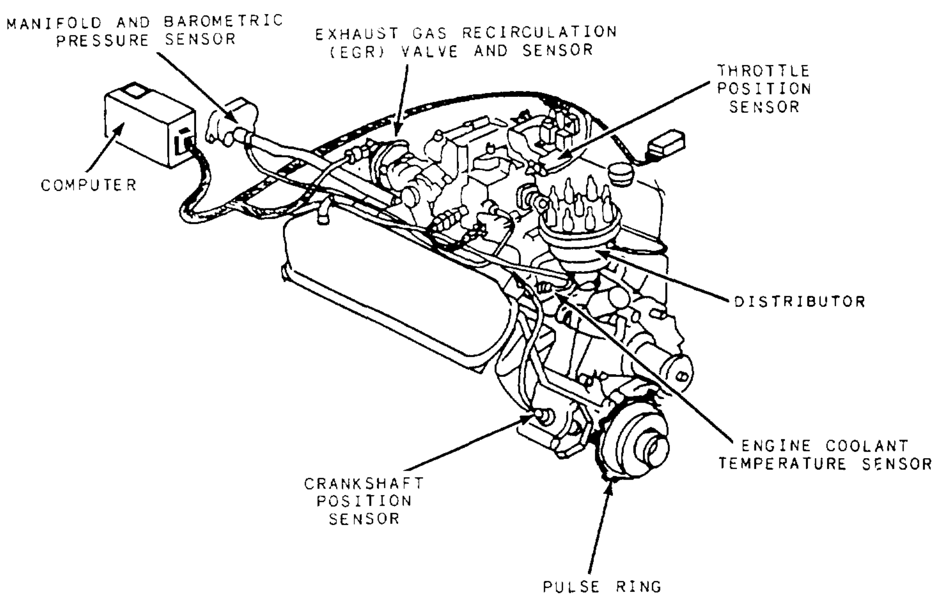


Figure 4-38.-Computer ignition components.

converted into a usable electrical signal. The ECA uses this reference for altitude-dependent EGR flow requirements.

Coolant Temperature Sensor

This sensor is located at the rear of the intake manifold and consists of a brass housing that contains a thermistor. When reference voltage (about 9 volts, supplied by the processor to all sensors) is applied to the sensor, the resistance can be measured by the resulting voltage drop. Resistance is then interpreted as coolant temperature by the ECA. EGR flow is cut off by the ECA when a predetermined temperature is reached. If the coolant temperature becomes too high (due to prolonged idling), the ECA will advance the initial ignition timing to increase the idle speed. The increase in engine rpm will increase coolant and radiator airflow, resulting in a decrease in coolant temperature.

Inlet Air Sensor

Inlet air temperature is measured by a sensor mounted in the air cleaner. It operates in the same manner as the coolant sensor. The ECA uses its signal to control engine timing. At high inlet temperatures (above 90°F), the ECA modifies the engine timing to prevent spark knock.

Crankshaft Position Sensor and Metal Pulse Ring

The crankshaft is fitted with a four-lobe metal pulse ring. Its position is constantly monitored by the crankshaft position sensor. Signals are sent to the ECA representing both the position of the crankshaft and the frequency of the pulses (engine rpm).

Throttle Position Sensor

The throttle sensor is a rheostat connected to the throttle plate shaft. Changes in the throttle plate angle varies the resistance of the reference voltage that is supplied by the processor. Signals arc interpreted by the ECA in one of the following three ways:

1. Closed throttle (idle or decelcration)
2. Part throttle (cruise)
3. Full throttle (maximum acceleration)

EGR Valve and Sensor

A position sensor is built into the EGR valve. The ECA uses the signal from the sensor to determine the position of the valve. The EGR valve and position sensor are replaced as a unit.

Distributor

The distributor is locked in place during engine assembly. Since all timing is controlled by the ECA, there are no rotational adjustments possible for initial ignition timing. There are no mechanical advance adjustments so there is no need to remove the distributor except for replacement.

Because of the complicated nature of this system, special diagnostic tools are necessary for troubleshooting. Any troubleshooting without these special tools is limited to mechanical checks of connectors and wiring.

DISTRIBUTORLESS IGNITION SYSTEM

Some later engines have no distributor as we know it. The distributor and ignition timing are all a part of an electronic control unit or ignition module (fig. 4-39). This system totally eliminates any vacuum or centrifugal advance mechanism and, in most cases, the

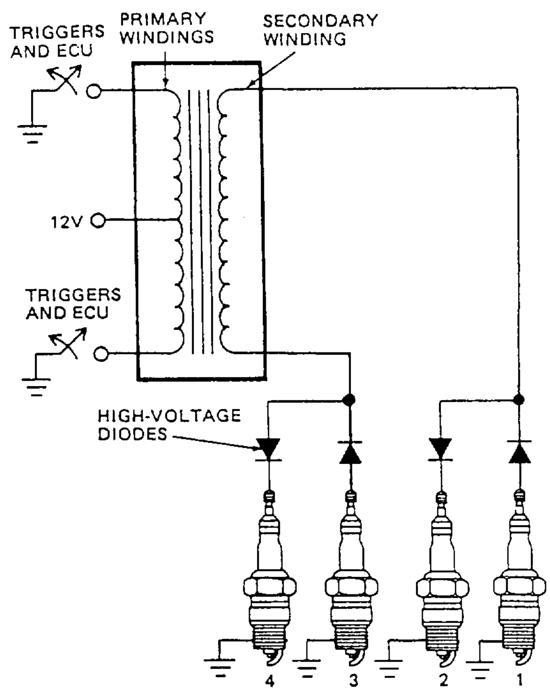


Figure 4-39.–Distributorless ignition system wiring diagram.

distributor itself. A crankshaft or camshaft rotating sensor (fig. 4-40) is used to provide the electronic control unit with piston position and engine speed. This signal is used to trigger the correct coil at the correct time for high-voltage spark. There are several types of this system currently on the market. For testing and repair, consult the manufacturer's maintenance manuals. Use only the correct tools and testing equipment when working on these units.

TROUBLESHOOTING

As an automotive electrician, you will be called on to troubleshoot the conventional, transistor, and electronic ignition systems. The instruments you need to pinpoint problems in a conventional ignition system include the simple voltmeter and ohmmeter. Although an engine analyzer simplifies the troubleshooting of electronic ignition systems, you can do so with a volt-ohmmeter (0 to 20,000-volt/ohm range). Better yet, you may use an ignition scope tester since it can test system components while the engine is running.

CONVENTIONAL/COIL IGNITION SYSTEM

To troubleshoot a conventional ignition system, you must conduct separate tests on the primary circuit (low voltage) and the secondary circuit (high voltage). The primary circuit carries current at battery voltage, whereas the secondary voltage could be as much as 30,000 volts.

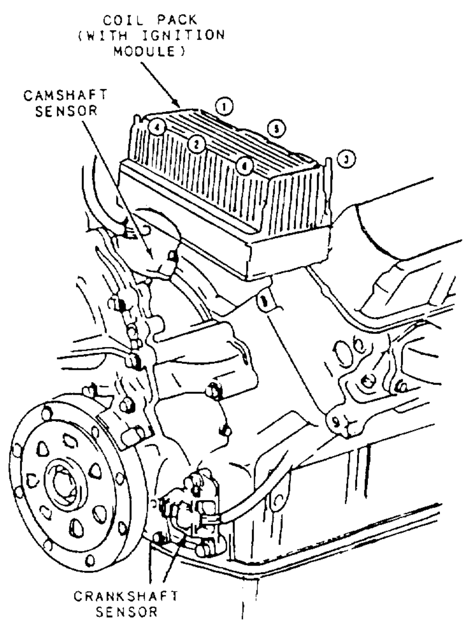


Figure 4-40.-Components of the distributorless ignition system found in some General Motors products.

Primary Circuit Tests

Using a simple voltmeter, you can check a 12-volt primary circuit as follows:

1. Hookup the voltmeter between the switch side of the ignition coil and a good ground. The engine must be at operating temperature, but stopped, and the distributor side of the coil grounded with a jumper wire. (See fig. 4-41.)

2. With the ignition switch on, jiggle it and watch the voltmeter. The switch is defective if the meter needle fluctuates. The voltmeter should read a steady 5.5 to 7 volts with the points open on systems using a ballast resistor.

3. Crank the engine and watch the voltmeter. It should read at least 9.6 volts while the engine is being cranked.

4. Remove the jumper wire from the coil; then start the engine. The meter reading should be 5 to 8 volts on a ballast resistor system while the engine is running.

5. Stop the engine by turning off the ignition switch. Hook up the voltmeter between the distributor side of the coil and ground. Remove the high tension wire from the coil and ground it.

6. Close the ignition switch and slowly open and close the breaker points by bumping the engine. When the points make and break the voltmeter should read between 4 and 6 volts. Normally, with the engine stopped and points opened, the reading will be 12 volts; with points closed, the reading will be near zero volts. If while the engine is cranked, the voltmeter reading

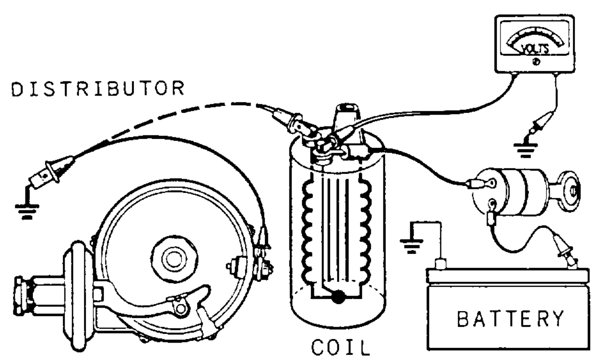


Figure 4-41.–Testing ignition primary circuit.

stays at zero or near zero, conduct the following three checks to locate the source of trouble:

- Check the current flow at the distributor. Disconnect the distributor primary wire from the top of the coil. Take a voltmeter reading from the distributor terminal of the coil. Current should flow through the circuit.

- Check the opening and closing of the breaker points. If not adjusted properly, they may not open and close. Also look for a mechanical failure of the points or cam. Lubricate the rubbing block at this time if necessary.

- Check grounding of the movable breaker point, the stud at the primary distributor wire terminal, or the wire of the condenser (pigtail). None of these should be grounded.

Secondary Circuit Tests

The high voltage in the secondary circuit is produced by the ignition coil. Current flows out of the coil at the secondary terminal through a cable to the distributor cap and rotor. The rotor distributes the current through the cap and cables to the spark plugs, and then to ground. The checkpoints for the secondary circuit are the secondary terminal of the coil, the coil-to-distributor cap cable, the distributor cap, rotor, spark plug cables, and spark plugs.

You should conduct the secondary circuit check as follows:

1. Pull the coil high-voltage cable from the distributor cap and hold the loose end of the cable about one-fourth of an inch from a good grounding point on the engine block.

2. Crank the engine and look for a spark to bridge the gap between the loose end of the cable and the grounding point. If you see a blue spark proceed to the next step since the coil is functioning normally. If you see a yellow spark or no spark at all, the trouble sources are in the primary circuit, the coil, and the coil-to-distributor cable.

3. Remove the sparkplug cables from sparkplugs and lift the distributor cap off. Connect one ohmmeter test lead to a spark plug cable connector and the other test lead to the terminal inside the distributor cap for the spark plug cable. Measure the resistance of the other spark plug cables in turn. Cable resistance should not exceed the manufacturer's recommendations. Excessive resistance can result from cable damage, defective spark plug connector, corroded distributor cap tower, or unseated cable in the tower.

4. Inspect the distributor cap inside and out for carbon tracking cracks, and inspect it for a worn center contact button or burned spark plug cable contacts.

5. Remove the rotor and inspect it. Look for high-resistance carbon, a burned tip, or a grounded rotor.

NOTE

> Because of the difference in materials and quality control used by manufacturers of distributor caps and rotors, you should use both items from the same manufacturer.

6. Remove all spark plugs from the engine and inspect each one. Look for fouled plug tips, gaps that are too wide or bridged, chipped insulators, and other conditions that can cause high resistance at the electrodes.

Coil Resistance Tests

You can use a simple ohmmeter to check the resistance of the ignition coil. Its primary circuit and secondary circuit are tested separately. To check the primary side, connect the ohmmeter leads across the primary terminals of the coil. Use the low ohms scale of the meter. The resistance should be about 1 ohm for coils requiring external ballast resistors and about 4 ohms for coils not requiring the ballast resistors. In checking the secondary side, switch to the high scale of the ohmmeter. Connect one ohmmeter lead to the distributor cap end of the coil secondary wire and the other lead to the distributor terminal of the coil. The condition of the coil is satisfactory if the meter reading is between 4,000 and 8,000 ohms, although the resistance of some special coils may be as high as 13,000 ohms. Should the reading be a lot less than 4,000 ohms, the secondary turns of the coil are probably shortened. A reading of 40,000 ohms or more indicates an open secondary, a bad connection at the coil terminal, or a high resistance in the cable.

TRANSISTOR IGNITION SYSTEM

The preceding techniques for troubleshooting a conventional battery/coil ignition system also apply, for the most part, to troubleshooting the basic types of transistorized ignition systems: breaker-point type and breakerless. Special techniques, however, are used in checking the electronic components of a transistorized ignition system. Before testing any electronic ignition system, refer to the manufacturer's manual. Not all systems may be checked for spark across a gap to ground without damaging the module. Other systems may only allow specific plug wires to be tested by sparking across the gap. Since these components are easily damaged by heat, shock, or reverse polarity, you must be extra careful in checking them. The following steps form the procedure for troubleshooting breakerless systems:

1. Pull the high-voltage cable from the distributor cap and hold the loose end of the cable about one-half of an inch from a good grounding point on the engine block.

2. With the ignition switch **ON,** crank the engine and look for a spark to bridge the gap between the loose end of the cable and the grounding point. If you see a blue spark, reconnect the high-voltage cable to the distributor and proceed to Step 3. If you do not see a spark or see a weak spark, proceed to Step 4.

3. Pull the cable from a spark plug and hold the loose end of the cable about one-half of an inch from the spark plug terminal. With the ignition switch **ON,** crank the engine and look for a spark to bridge the gap between the loose end of the spark plug cable and spark plug terminal. A blue spark here indicates a normal operating condition.

4. With a weak spark or no spark, test the coil. Since a special coil is used in this ignition system, you cannot test it with a conventional coil tester. Use an ohmmeter to check the continuity of the primary and secondary windings of the coil. With leads disconnected from the coil, connect the ohmmeter across the primary terminals. If the meter reading is infinite, the primary winding is open. The

Table 4-1.-Troubleshooting Chrysler Electronic Ignition

Condition	Possible Cause	Corrrection
ENGINE WILL NOT START (Fuel and carburetion known to be OK)	a) Dual Ballast	Check resistance of each section: Compensating resistance: .50-.60 ohms @ 70°-80°F Auxiliary Ballast: 4.75-5.75 ohms Replace if faulty. Check wire positions.
	b) Faulty Ignition Coil	Check for carbonized tower. Check primary and secondary resistances: Primary: 1.41-1.79 ohms @ 70°-80°F Secondary: 9,200-11,700 ohms @ 70°-80°F Check in coil tester.
	c) Faulty Pickup or Improper Pickup Air Gap	Check pickup coil resistance: 400-600 ohms Check pickup gap: .010 in. feeler gauge should not slip between pickup coil core and an aligned reluctor blade. No evidence of pickup core striking reluctor blades should be visible. To reset gap, tighten pickup adjustment screw with a .008 in. feeler gauge held between pickup core and an aligned reluctor blade. After resetting gap, run distributor on test stand and apply vacuum advance, making sure that the pickup core does not strike the reluctor blades.
	d) Faulty Wiring	Visually inspect wiring for brittle insulation . Inspect connectors. Molded connectors should be inspected for rubber inside female terminals.
	e) Faulty Control Unit	Replace if all of the above checks are negative. Whenever the control unit or dual ballast is replaced, make sure the dual ballast wires are correctly inserted in the keyed molded connector.

secondary winding is checked by connecting the ohmmeter to the coil case and to the high-voltage center tower. Again, an infinite reading indicates an open winding; if any reading is obtained, it indicates a shorted winding. Be sure to use the middle- or high-resistance range of the ohmmeter when you check the continuity of the secondary winding.

5. Check the operation of the ignition pulse amplifier by detaching the positive and negative leads from the coil and connecting them in series to a 12-volt, 2-candlepower bulb.

6. Crank the engine and observe the bulb. If it flickers on and off, the amplifier is operating properly. If the bulb does not flicker on and off, check the distributor.

7. Connect a vacuum source to the distributor and an ohmmeter to the two terminals on the distributor connector. Open the vacuum source to the distributor, and observe the ohmmeter throughout the range of the vacuum source. A reading less than 550 ohms or more than 750 ohms indicates a defective pickup coil in the distribute.

8. Remove one ohmmeter lead from the distributor connector and ground it. Again, open the vacuum source to the distributor as you observe the ohmmeter. A reading less than infinite indicates a defective pickup coil.

ELECTRONIC IGNITION SYSTEM

Provided the engine analyzer is not available, you may troubleshoot the electronic ignition system to prevent unnecessary replacement of its expensive units. (See table 4-1.) You will need a volt/ohmmeter with a 20,000 volt/ohm range. Check the battery in the system being tested; battery voltage must beat least 12 volts.

CAUTION

Make sure the ignition switch is off when the control unit connector is being removed or replaced.

Disconnect the wiring plug from the control unit, and turn on the ignition switch. Ground the negative voltmeter lead. Connect the positive voltmeter lead to the harness cavities designated in the sequence recommended by the manufacturer. Voltage should be within 1 volt of battery voltage with all accessories off. If not, check that circuit through to the battery. Turn the ignition switch off after completing the voltage test. Connect the ohmmeter to the cavities designated. If resistance is not within the manufacturer's range, disconnect the dual lead connector from the distributor. Recheck resistance at the dual lead connector. With one ohmmeter lead still grounded, connect the other lead to either distributor connector. If the ohmmeter shows a reading, replace the distributor pickup coil. To test for control unit continuity, ground one ohmmeter lead and connect the other lead to the control unit pin designated. If continuity cannot be obtained after removing and remounting the control unit in an attempt to get good ground, replace the control unit. Make sure the ignition switch is **OFF,** and reconnect the control unit connector plug and the distributor plug. Check the air gap adjustment as described previously. After these tests or repairs, test the entire system by removing the center wire from the distributor cap. Using insulated pliers and a heavy rubber glove, hold this wire about one-half of an inch from the engine block and operate the starter. If there is no spark replace the control unit and retest. If no spark is obtained, replace the coil.

TROUBLESHOOTING LIGHTING SYSTEMS AND ELECTRICAL ACCESSORIES

Most modern automotive and construction vehicles (Military Tactical CESE included) have up to 60 or 70 lights and numerous electrical accessories, such as small motors, gauges, solenoids, and switches. Each one of these devices presents a new troubleshooting problem to the CM1. To perform these tests, you need a few simple hand tools, such as screwdrivers, pliers, a 12/24 volt test lamp, and most important, a volt/ohmmeter (fig. 4-42). For routine testing of burned out light bulbs,

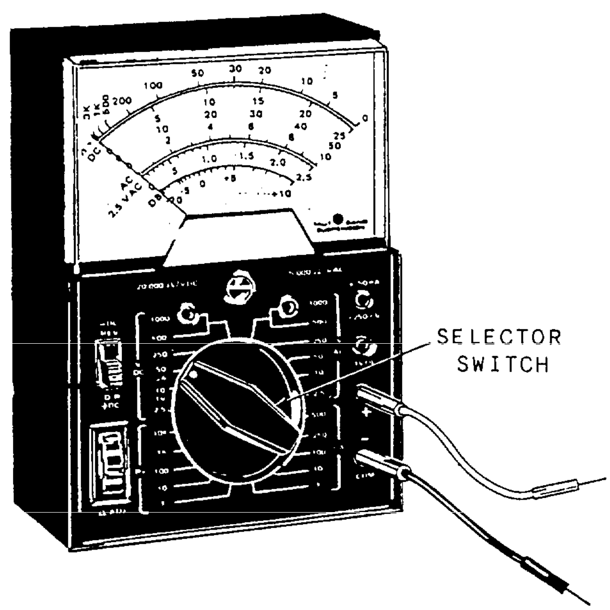


Figure 4-42.-Typical volt/ohmmeter.

burned fuses, or corroded battery terminals, a technical manual may not be required; however, for more complex, electrical systems, it is a necessity. Use EXTREME CAUTION when working around any electrical system on any CESE. Crossing wires or flashing wires to ground-to check for current may all lead to major damage, costly repairs, or personnel injury.

When you troubleshoot any system, have a set plan to approach the problem. Keep it simple; eliminate easy items, such as a dead battery, burned out light bulbs, blown fuses, and so forth. Once the simple fixes are out of the way, use your own set plan to solve the problem. One plan that may be of help to you is the following:

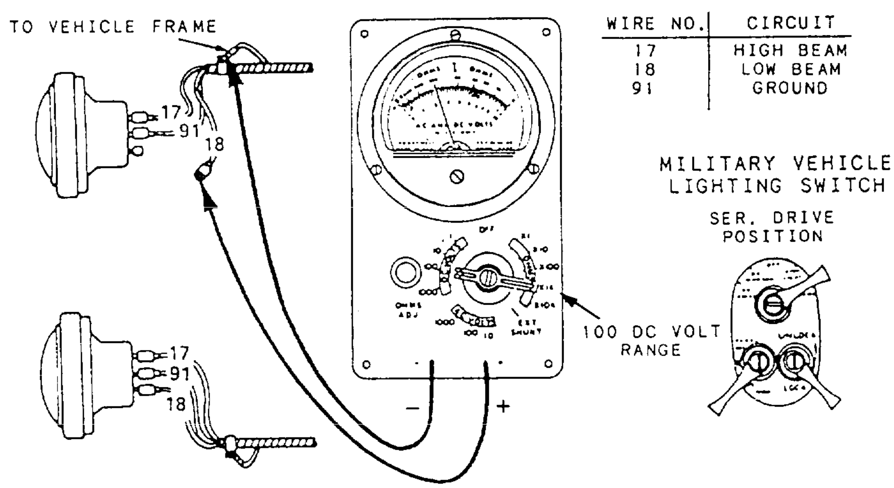
1. Know the machine and find and read the technical manual to understand the problem.
2. List all the possibilities of the fault.
3. When possible, speak to the operator and find out how the unit malfunctioned in a working situation.
4. Operate and inspect the machine yourself.
5. Systematically test individual circuits until the problem is found.
6. Test your findings.
7. Repair CESE and return it to service.

As an afterthought, once a unit of CESE is repaired and returned to dispatch, discuss your findings with other CMs in the shop. Do not play, *I've Got a Secret* with repair information.

Before proceeding with any electrical tests on automotive or construction equipment, check the power source (battery) and its connections first. A dead or poorly grounded battery may not light lights, work solenoids, or run motors. On the other hand, a poorly grounded battery may work many of the vehicle components, but not certain electronic circuits. Remember to check the battery and its connections first; for the remainder of this chapter, before any troubleshooting procedures are explained, it will be assumed that you have done so.

HEADLIGHTS

The most common problem in headlight systems is burned out light bulbs. This may be eliminated simply by replacing the bulbs. If the head lamp still does not work, remove the lamp from the socket and check the leads on the multiwire connector to the lamp with a 12/24 volt test lamp or a volt/ohmmeter (multimeter) (fig. 4-43). Make sure the headlight switch is turned on.



WIRE NO.	CIRCUIT
17	HIGH BEAM
18	LOW BEAM
91	GROUND

Do the following steps to check for voltage to the headlights:

Step 1. Refer to the table above and pick the wire number for each headlight, high or low beam, that is not working. Disconnect that wire from the back of the headlight.

Step 2. Turn lighting switch to "SER. DRIVE" position.

Step 3. Set switch on meter to "100 DC VOLTS" position.

Step 4. Connect red probe to the disconnected wire and black probe to a good ground.

Step 5. If wire 17 and 18 show 24 volts, the problem is in the headlamp. If a zero reading is observed at wire 17 and 18, check the dimmer switch and light switch.

Figure 4-43.-Troubleshooting headlight wiring (typical military system).

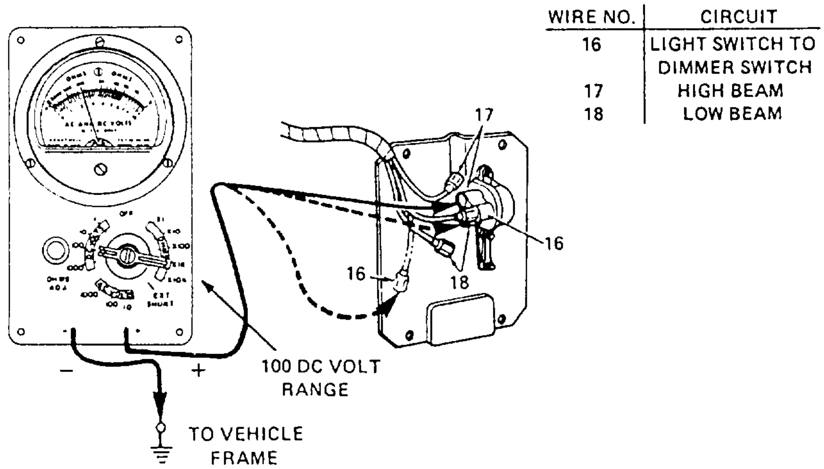


Figure 4-44.-2 1/2-ton military truck foot-operated dimmer switch electrical test.

Obtain a wiring diagram for the particular system you are working with, and trace the circuit back to the next major multi wire connector, then to the light switch itself. Remember, try to avoid unnecessary cutting into wiring looms or harnesses as this type of damage causes moisture to be allowed into the wiring system.

If the headlights do not switch from low beam to high beam, find the dimmer switch (foot operated or steering column mounted), then refer to the wiring diagram (fig. 4-44) and test for voltage.

In the case of all of the headlights being out at the same time, check the fuse; then check for power flow to the light switch. If necessary, remove the light switch from the vehicle and test it on the bench.

The problem of dim headlights could mean the following things:

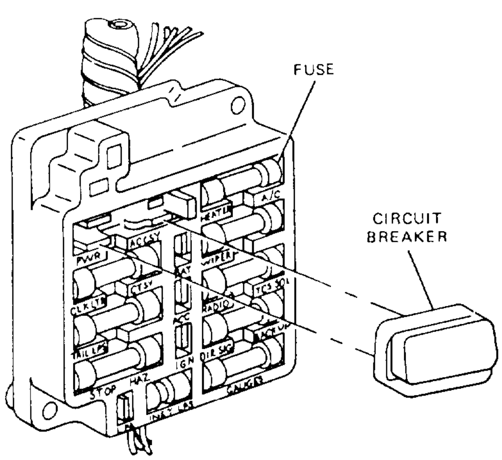


Figure 4-45.-Fuse block with fuses and circuit breaker.

- Low battery voltage
- Poor connections in the circuit
- Faulty ground wires
- Incorrect voltage head lamps

FUSES AND CIRCUIT BREAKERS

Fuses or circuit breakers are put into electrical circuits to prevent damage from electrical overload. Normally, fuses are mounted in a cluster or fuse block (fig. 4-45). Some may be remotely mounted away from the fuse block, in which case, you will have to get under the dashboard or hood and hunt for them. Still others may be mounted within the circuitry of the accessory (fig. 4-46) that you are testing. Fusible links are usually marked and mounted close to the battery.

Testing fuses is quite simple. You should use a 12/24 test lamp. Attach one end to a good ground, energize the circuit, and use the probe to test both ends of the fuse. If a burned fuse is found, keep in mind there is a reason for it. Trace the circuit and find the fault before replacing the fuse.

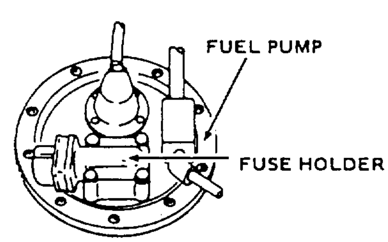


Figure 4-46.-Example of an accessory mounted fuse.

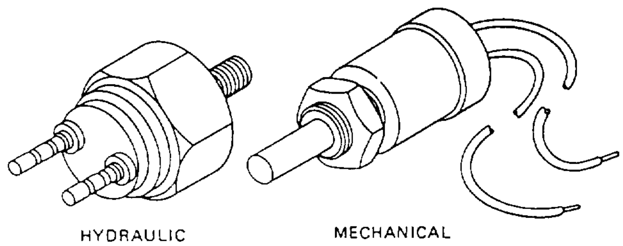


Figure 4-47.-Typical stoplight switches.

CAUTION

Never bypass a fuse or circuit breaker by using tinfoil or direct wire method. Always use the correct amperage rating when replacing any fuse or circuit breaker.

DIRECTIONAL SIGNALS

Troubleshooting directional signals may be somewhat complicated due to the fact that most of the turn signal switches, flashing units, and much of the wiring is located under the dashboard or in the steering column. In addition, the most common design for a turn signal system is to use the same rear lamps for both the stoplights and the turn signals. This somewhat complicates the design as the brake light circuit must pass through the turn signal switch. As the left or right turn signal is energized, the stoplight circuit for that circuit is opened and the turn signal circuit for that circuit is closed.

NOTE

When this type of circuit is used, the front indicator lamps and front signal lights must be on a separate signal switch circuit.

To troubleshoot this type of switch, first find the multiwire connector joining the main wiring harness to the signal switch harness. Use a 12/24 volt test lamp and the manufacturer's maintenance manual as a guide. Test the input and output of the switch. If the switch is at fault and must be replaced, usually the steering wheel has to be removed before the switch maybe removed.

Failure of the signal lights to flash is usually caused by the flasher unit. A flasher unit is a nonrepairable item mounted under the dashboard or on the fire wall.

BRAKE LIGHTS

The two types of brake light switches are hydraulic and mechanical (fig. 4-47). These may be mounted under the dashboard, on the master cylinder, or on the vehicle main frame. To test the switch, first check for power to the switch. Then using a 12/24 volt test lamp, touch the probe to the output terminal of the brake light switch and apply the brakes. If the test lamp lights, the switch is good. If the test lamp does not light, the switch is defective and must be replaced.

HORNS

The current draw of a horn is very high; therefore, it is usually operated by a relay (fig. 4-48). The control switch (horn button) is almost always mounted in the

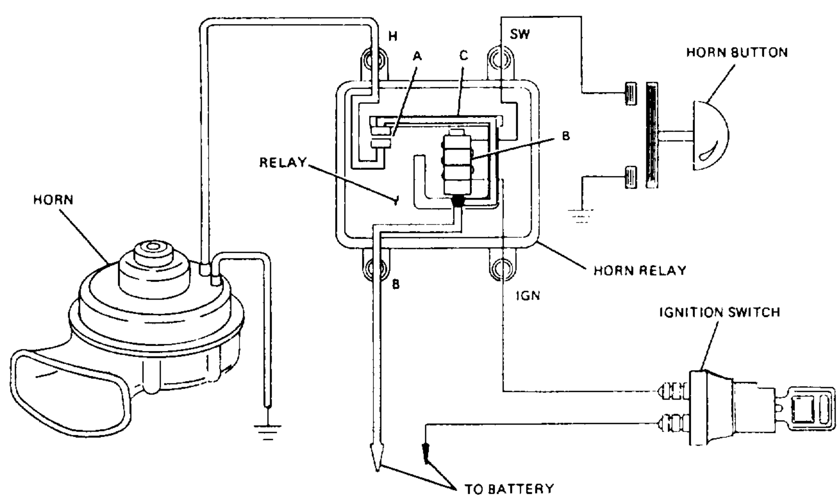


Figure 4-48.-Typical horn circuit using a relay.

center of the steering wheel. Refer to figure 4-4 for troubleshooting. In testing the horn circuit, first find the horn relay. Normally, it is mounted under the hood in the engine compartment. Next, check for voltage at terminals B, ING, and SW. If voltage is present at the relay, switch the probe to terminal H and depress the horn button. If the test lamp lights, the relay is good. Check the horn.

SMALL ACCESSORY MOTORS

Small accessory motors are used to drive cooling and heating fans, windshield wipers, fuel pumps, and so forth. Since most of these motors are basically the same, troubleshooting is reasonably simple. The hardest part may be getting to the motor. Normally, troubleshooting procedures are as follows:

1. Check the fuse.
2. Turn the motor by hand when possible. Some obstruction may be causing it to jam, overloading the circuit and blowing the fuse.
3. Check for power at the last multiwire connector going to the motor. Be sure power is arriving at the motor.
4. Look for burned wiring and loose connections. Burned insulation will be discolored and will smell burned.
5. Troubleshooting of small electrical accessory motors is similar to continuity and ground tests performed on starting motors mentioned earlier in this chapter.
6. Repair the motor according to manufacturer's specifications.

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